PRODUCT ENGINEERING

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Another Golden Opportunity Is Here

EVERY CLOUD has its silver lining and every situation presents its opportunities. There are those, companies and individuals, who work, strive and scramble, but only when an insistent demand calls forth their efforts. And as soon as the demand subsides they relax, take it easy, and loaf, bemoaning the fact that there is nothing to do. And, in various degrees of despondency, they await the return of the demand so that they may again work, strive and scramble.

But the same demand never comes again. During the lull of business inactivity, the minds of others have been working—improving the old and creating new. Metallurgists and chemists have been experimenting; scientists have evolved new theories. New knowledge, new materials and new devices have come into being. And designing engineers, applying the new as it becomes available, have developed improved products.

No, the demand is never the same when it returns. The world moves in cycles, but always advancing cycles. Standing still means marching to the rear, for the world is always moving forward. For those who sit and wait to be goaded into activity by a returning demand, when business does pick up it is a mad hectic scramble to make up for lost time that can never be regained. They can never quite catch up to those who planned carefully, worked steadily and created advanced designs of new products while business was slack.

All this sounds trite to many. On the other hand, there are some who consider research and product development during business recessions as an ideal that is impracticable and rarely should be attempted. Which of these viewpoints is the more general and profitable?

To analyze the present, look at the past. Less than ten years ago we were in the midst of the worst depression the world has ever known. But in 1935 when the National Machine Tool Show was held in Cleveland, Ohio, even the machine tool manufacturers themselves were surprised at the new designs on exhibit. And users of machine tools were astounded. But this was only one example. It was also during that depression that Budd developed the stainless steel streamlined trains, that General Motors perfected their 900 hp. diesels, and that Crompton & Knowles developed their line of Cotton King looms. Innumerable other examples could be cited. Thousands of products were redesigned to use stainless steels and plastics. Automatic controls, hydraulic drives, electronic devices and new mechanical parts were developed and applied. Is history repeating itself during this recession? We felt it is but did not have enough facts upon which to base conclusions. So we investigated. Companies were selected at random and we wrote to them, addressing our inquiry to a responsible official.

In this issue of *Product Engineering*, pages 103 to 105, we present reports on the design development activities in a number of companies, large, small and medium sized. The records speak for themselves. Although we are not prepared to prove that every leading successful company carries on, regardless of business conditions, an uninterrupted program of engineering design development, the facts indicate that those that do are successful companies.

What are you going to say when your prospects ask, "How have you improved your product during the past year?" Is your company among the small minority that is marking time, or is it profiting during the lull by creating new demands through product improvement? Another golden opportunity is here and if your company can't see it, perhaps it is also your opportunity to point it out and lead the way.

Fig. 1—Drafting room—Bell Telephone Laboratories

DRAFTING ROOM PRACTICES–I

Personnel and Procedure

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Organization, personnel training and procedure for economical production and efficient cooperation with engineering and manufacturing divisions. A concluding article, dealing with simplified drafting methods, will appear in the April number

THREE MAIN STEPS in the production of a new manufactured product are (a) originating and developing an idea, (b) working out the specific design on paper, and (c) making the apparatus in the shop. In the most elementary form of an engineering-manufacturing organization, all three of these steps may be performed by one man and many problems may thus be avoided. However, as development and manufacturing are usually handled under present day conditions, each of these steps involves constant effort of a functionalized department.

The first step is performed by a department of development engineers, called hereafter the Engineering Department. The third step is performed by the Manufacturing Department. Between these two is the organization with which this discussion is principally concerned, namely, a Drafting Department, which, under the direction of the Engineering Department, supplies the Manufacturing Department with drawings containing all the information on physical requirements needed for the manufacture of the apparatus.

Such a department has, as a nucleus, a group of men who, as a result of innate ability, training, experience, and temperment are capable of proceeding with

the mechanical processes of design upon instructions which may be simply a verbal description of the function to be performed by the proposed apparatus, rough sketches outlining fairly completely the ideas of the development engineer, or something between these two extremes, depending upon the complexity of the apparatus to be shown on the drawings. These design draftsmen are assisted in their work by detailers and tracers, who perform functions requiring less experience with, and less knowledge of, materials, manufacturing processes, etc. In some of these assistant-type jobs, particularly those involving tracing and lettering, women are being used to good advantage.

This group of design draftsmen and their assistants, the Drafting Department, must work as a team member toward the overall efficiency of the team as a whole. It must endeavor to help the Engineering Department by interpreting ideas accurately with a minimum of information and effort, and must supply to the Manufacturing Department drawings which present the requirements in the simplest and clearest manner and which do not tend to hamper the Manufacturing Department by the specification of immaterial detail. All of this must be done with a critical eye constantly upon the Drafting Department's own practices to insure that drawings of proper quality are produced in the most inexpensive manner that is currently available.

Some of the experiences of Bell Telephone Laboratories in trying to improve this phase of its activities may be helpful to workers in other engineering fields; and it is hoped that discussion of such experiences will bring forth suggestions along similar lines from other organizations where the problems involved in large scale preparation of drawings are currently being solved by methods not generally known.

Personnel Training

Well trained and versatile design draftsmen are not too plentiful. It is necessary, therefore, for any large drafting department to train its proper share of men, because this is the one way of insuring a continuous supply of men who will become successful along this line. For the beginners, training should not be confined to practical work on the drafting board, but should include a well planned course in classroom work conducted by competent teachers.

Fig. 1 shows a new group of student draftsmen performing on the boards the practical functions of simple drafting which occupy them for six hours each day. Fig. 2 shows this same group in one of the Personnel Department's classrooms where one hour each day is spent in fundamental instruction. Such instruction is planned, of course, with a view to assisting these recent high school graduates toward more useful and more remunerative accomplishment.

In the course of training, as in other educational processes, the fundamentals should be stressed so that the man will not become specialized at so early an age as to detract from his adaptability to various kinds of jobs in later years. After such training has been effected, however, economical operation dictates specialization.

For this reason, the force of experienced design draftsmen and assistants is divided into relatively small groups, and each group is made responsible for the preparation of drawings in connection with a general type of apparatus. This, of course, does not close the door to further training through change of specialty from time to time. Such changes will come about normally due to slack periods in one line occurring simultaneously with peaks in other lines. Nevertheless, at any given time there should be available a group in which the majority of members is exceptionally well schooled in preparing drawings on any given type of apparatus in the general line involved. Such a group will not only complete its work with the greatest efficiency and speed, but will also be able to start a project with relatively meager information from the development engineer and carry it through to completion with the minimum amount of supplementary information. This, of course, relieves the engineer to devote more time to other jobs.

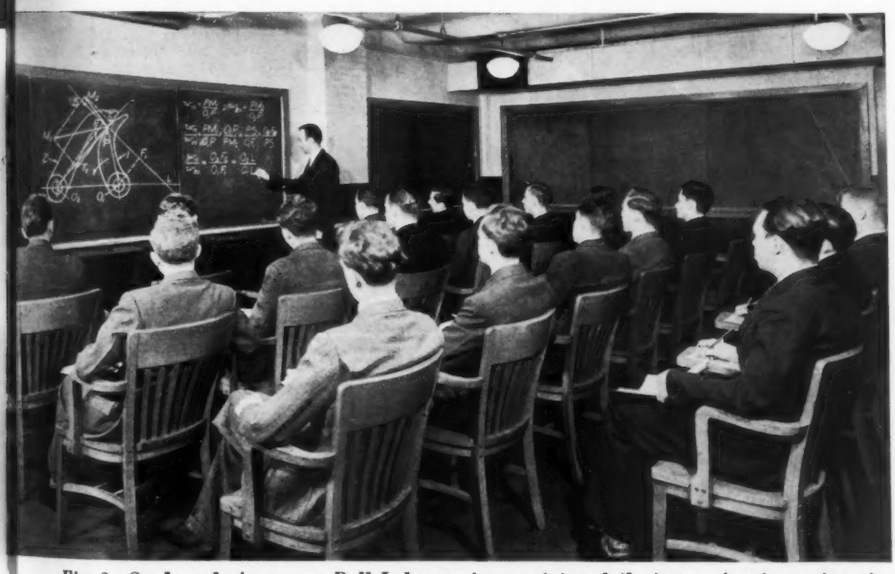


Fig. 2—Student draftsmen at Bell Laboratories receiving daily instruction in engineering

Turnover of Trained Personnel

Although, as stated above, every organization which employs draftsmen should plan to train its share of men, it should never at any time be made up completely of men trained within the organization. Some admixture of experienced personnel from other organizations is helpful, since such trained men bring with them valuable contributions, particularly if their experience has included some shop work. They prevent the department from becoming too inbred. Similarly, although every organization should, by means of its promotional opportunities, endeavor to hold the good men which it trains, the loss of a few experienced men to other organizations is to be regarded merely as the normal course of an active group with its complement of more venturesome spirits. In fact, the overall economic effect of movements of personnel, even on this score, can often be utilized for advancement of junior personnel. To provide incentive for high grade work, design draftsmen who show originality and are otherwise qualified should be advanced to engineering positions.

Importance of Checking

No matter how carefully drawings are prepared and no matter how much confidence a supervisor may have in his men, careful checking is necessary, particularly when the drawings are to be used in connection with large scale production where discrepancies would be costly. Placing a set of unchecked drawings in the hands of the Manufacturing Department would be comparable to approving press forms for a new mathematical treatise without having proofs drawn and carefully compared with the author's copy. Checking of drawings is done, in general, by the group supervisor, but in some types of

jobs he may have to obtain help from others who have been specially trained to render such help from time to time.

Checking insures that the information is in accordance with standard design practices, that the design is correct as to strength, appearance, finish, convenience of assembly, and maintenance; that, in the design of parts, due consideration has been given to the use of materials of standard stock sizes; that castings have the proper draft without affecting thickness or clearance; that all information for fabricating each part has been specified; that the broadest tolerances commensurate with a satisfactory product have been allowed; that cumulative allowable variations of parts will not cause the completed apparatus to exceed the allowable variation for the complete assembly; that associated parts will mount properly; that dimensions given are those of use to the shop man so that he will not be obliged to make calculations; and a number of other things which experience has taught the checker to consider.

Checking from Prints

When a job is ready for checking, the natural and obvious thing is to take the originals and simply check them. Such a procedure has been found to possess a number of disadvantages, however, and it is felt that it is well worth while to have preliminary blue prints made of the unchecked tracings (or vellum paper drawings) and then do the checking work from the prints. As the checker proceeds he finds it necessary to make a number of marks upon the blue prints to indicate things which he has found to be correct and also to indicate where changes are required. If the tracings or other originals are used for checking purposes, all such marks must later be removed. This takes time and tends to wear out the drawings. Moreover, it destroys the record of the check which may be useful later. On the other hand, when checking is done from blue prints, the expense of erasing check marks and change notations is saved; the originals which will, during the course of their lives, be required to withstand all too much handling are saved this initial bit of maltreatment; and the check record is preserved for a reasonable time so that it may be examined by the head of the department if he should choose to study the work of any of his men with regard to accuracy or completeness.

Indexing and Preserving Records

For drawings to be of maximum benefit to the organization, they must, of course, be properly indexed and filed so that they will be well protected against damage or deterioration. At the same time they must be accessible to those who need to use them. Care must be taken to insure that originals are not used for purposes that could just as easily be served by prints, as in the case of checking mentioned above. Moreover, relatively inactive drawings containing records which should be preserved, may be recorded on film and the originals destroyed; or they may be stored in cheap space or in space which is not readily accessible. These various functions require filing facilities commensurate with the value and activeness of the records. In Fig. 3 is shown a file room where nearly a million and a half pieces of engineering information in the form of drawings, specifications, etc., are recorded, stored, and dispensed promptly to those requiring them in connection with further development activities.

Simplification of Practices

Some of the drawings of years gone by were indeed works of art, but many of their embellishments were needless, and the artist was, therefore, ill paid for his pains simply because it is uneconomical in a well-managed industry to pay for details which serve no utilitarian purpose. Moreover, as more and more complex mechanical devices came into the service of society, it became increasingly necessary to step up drafting production. The recent trend, therefore, has been toward simplifying practices in such a way as to eliminate lost motion.

Production of such drawings rapidly, accurately, and economically, requires a continuous program of standardization. While the drafting room should be concerned principally with standardization as it affects drafting methods, many opportunities will arise for the initiation or promotion of design standardization. Such opportunities should not be neglected by a Drafting Department that is striving toward higher efficiency for the Engineering-Drafting-Manufacturing team.

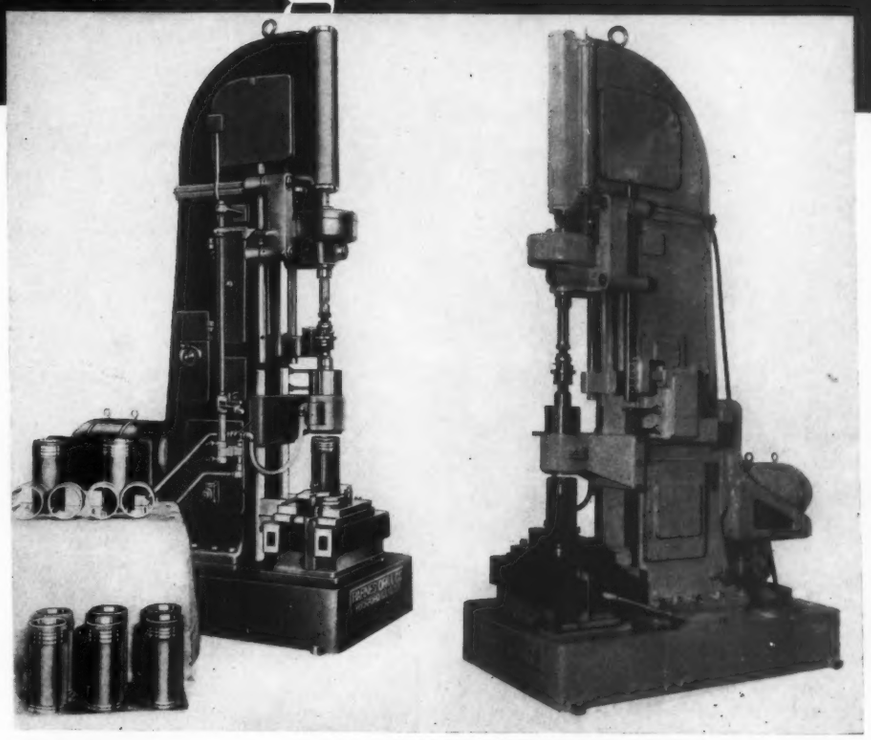
(*Concluded in April*)

Fig. 3—Drawing and specification files — Bell Telephone Laboratories

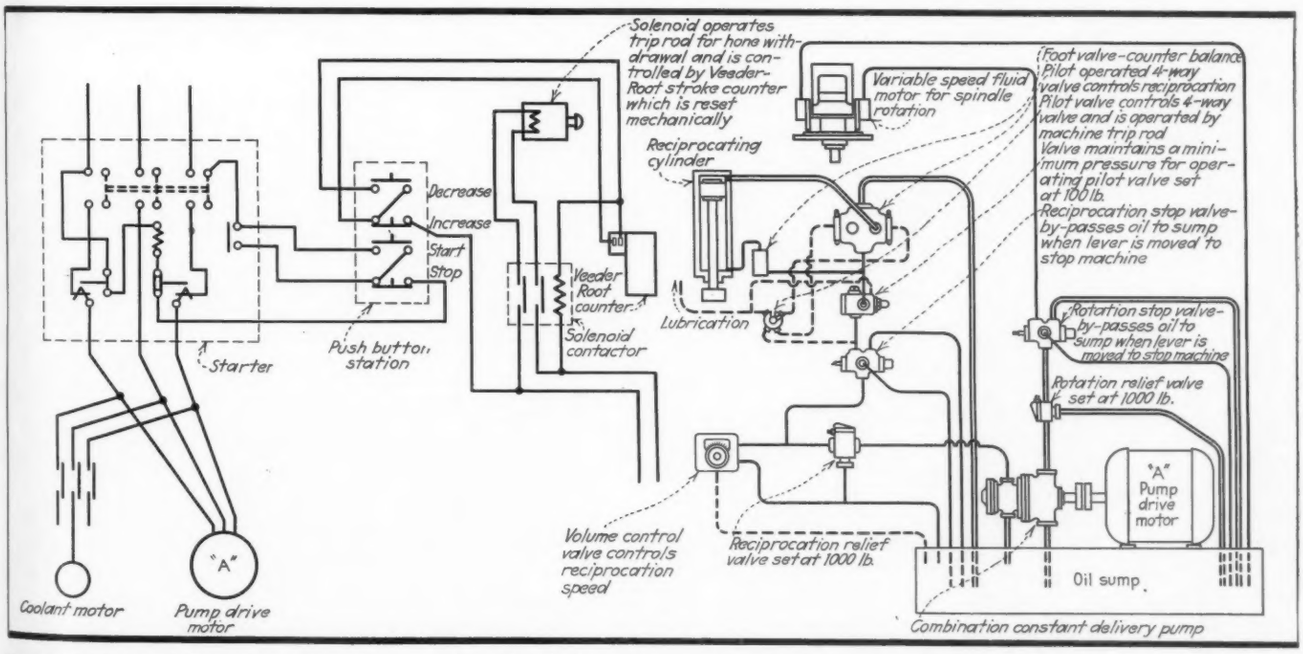
Modern Designs

Variable-Speed Hydraulic Drive Transmission

HYDRAULICALLY reciprocated honing machine designed and built by Barnes Drill Company is designed with a Vickers variable-speed hydraulic transmission built into the top section to provide any increment of speed between 100 and 250 r.p.m. Other ratios, higher or lower, are also obtainable. Machine illustrated has a capacity for driving up to 10 in. diam. hones, has 20 in. vertical travel. The vertically travelling reciprocating carriage runs on angular contacting antifriction bearings, mounted on hardened steel vertical shafts adjustable to take up all play.



Control lever at the extreme left of the column adjusts rate of spindle rotation. Tachometer on reciprocating head indicates speed. The other lever controls rate of reciprocations. Air cylinder counterbalance is above carriage. Spindle drive consists of three spiral gears at the top, through reduction gears in reciprocating carriage which drive stubby spindle.


Solenoid operates trip rod for hone withdrawal and is controlled by Veeder-Root stroke counter which is reset mechanically
Variable speed fluid motor for spindle rotation
Foot valve-counter balance
Pilot operated 4-way valve controls reciprocation
Pilot valve controls 4-way valve and is operated by machine trip rod
Valve maintains a minimum pressure for operating pilot valve set at 100 lb.
Reciprocation stop valve-by-passes oil to sump when lever is moved to stop machine
Reciprocating cylinder
Decrease
Increase
Start
Stop
Veeder Root counter
Solenoid contactor
Lubrication
Starter
Push button station
Rotation stop valve-by-passes oil to sump when lever is moved to stop machine
Rotation relief valve set at 1000 lb.
"A" Pump drive motor
Volume control valve controls reciprocation speed
Reciprocation relief valve set at 1000 lb.
Oil sump
Coolant motor
Pump drive motor
Combination constant delivery pump

Electric and hydraulic systems are interlocked by means of solenoid which operates the trip rod that in turn operates the pilot valve controlling a four-way valve. Solenoid circuit is also controlled by Veeder-Root counter that is reset mechanically for number of strokes desired. Coolant motor and pump drive motor are controlled from pushbutton station. Volume control valve is set manually to give desired speed to reciprocating head, while speed of spindle rotation is adjusted by control lever to give desired spindle r.p.m. indicated by tachometer. Lubrication is furnished to gearing and sleeve by oil from the hydraulic operating system. Foot valve, set at 200 lb. per sq. in., maintains this pressure on underside of reciprocating piston to counterbalance the weight of the reciprocating parts.

Modern Designs—General Motors' New Diesels

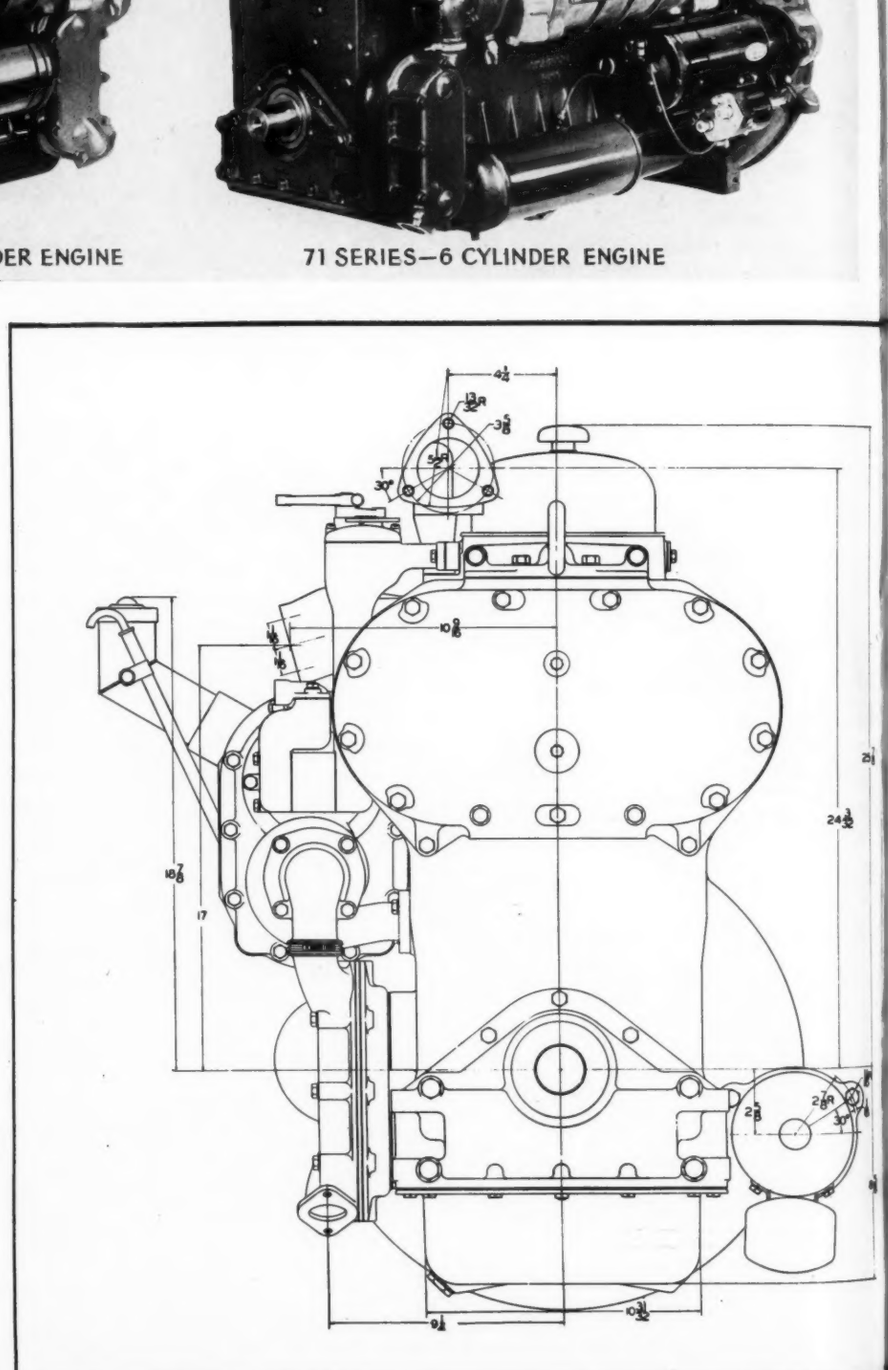
71 SERIES—3 CYLINDER ENGINE

71 SERIES—6 CYLINDER ENGINE

Size, weight and power, comparable to gasoline engines, were obtained in General Motors Diesel engines by use of two-cycle and uniflow principle in a strengthened, conventional 4-cycle gasoline engine-type structure. Maximum interchangeability of parts between different models was aimed at to cut costs.

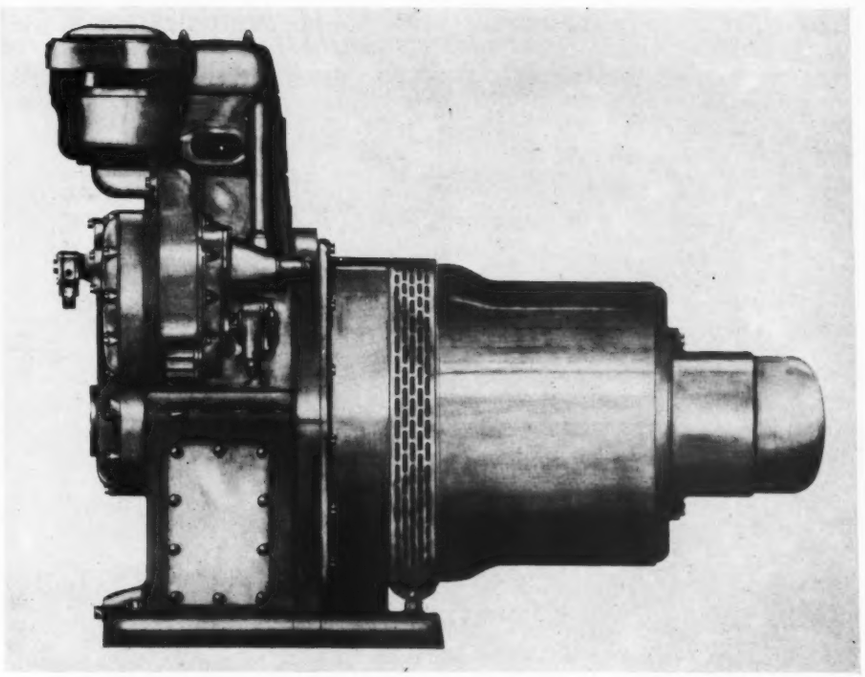
The cylinders are the same for all models in the 71 series, which have 1, 3, 4 or 6 cylinders. The front end of the cylinder block of all models is exactly like the rear end, and the cylinder head, blower, bearings and similar parts are all alike at each end. The only difference between the 3 and the 6 is that three more cylinders are added in the middle of the engine, and the crankshaft, camshaft, and blower lengthened accordingly. Pistons, valve gears, connecting rods, bearings, pumps and other such parts are identical for all models and completely interchangeable.

Cylinders are cast en block with removable dry liners. Cylinder head is a one-piece removable unit with overhead valves operated through rocker arms and push rods. Blower is flange-mounted on the side of the cylinder block discharging directly into the air box. The water pump, fuel transfer pump and governor are mounted on, and driven by, the blower. All pan and valve covers are one-piece steel stampings. By turning the cylinder block and blower assembly end for end, all the accessories can be placed on either side without disturbing flywheel or gear train. Crankshaft rotation can be made clockwise or counter-clockwise by shifting one gear in the gear train and changing camshaft and oil pump cover.

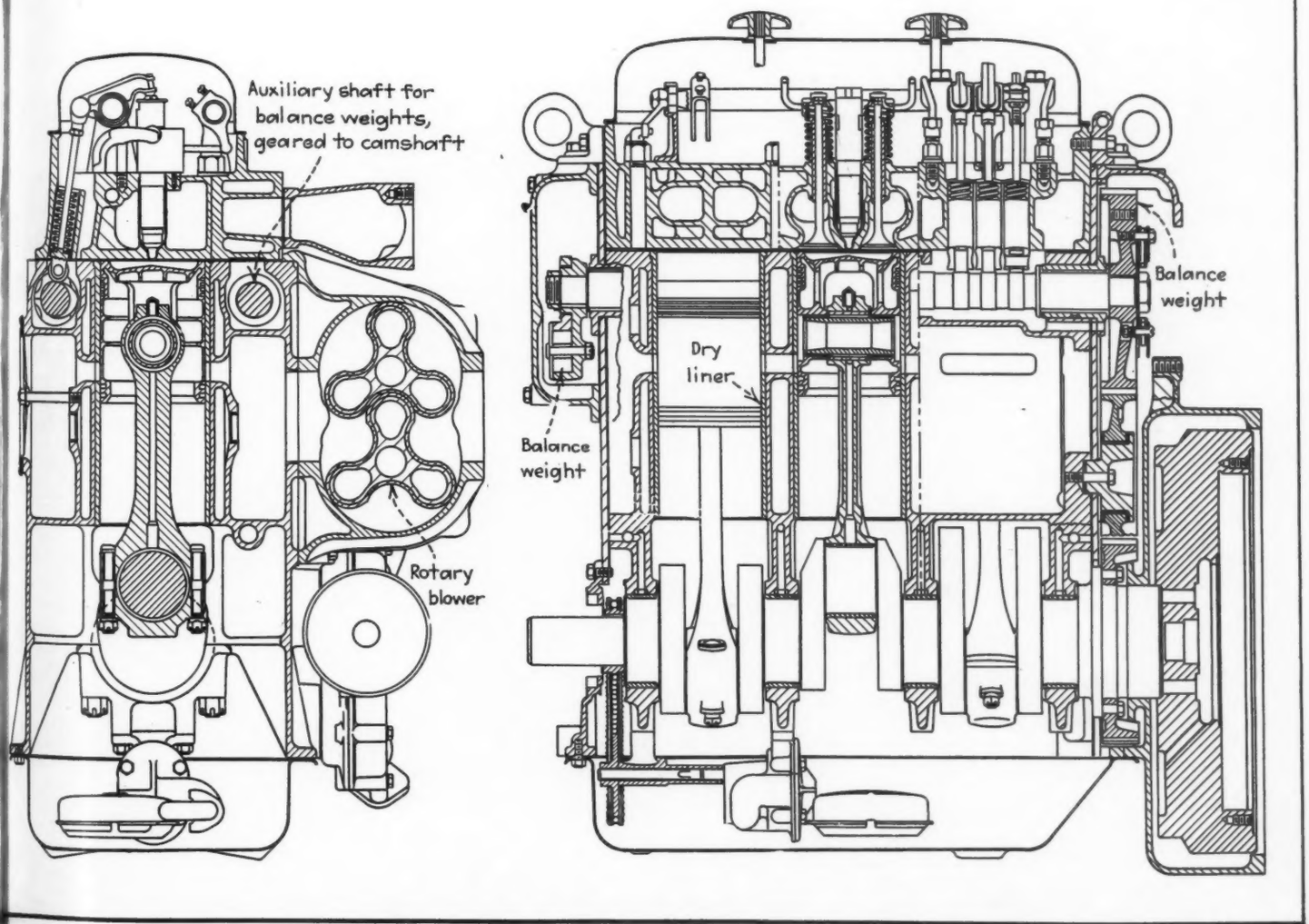


Feature of engine design is the provision for balancing out the fore and aft rocking couple in the vertical plane produced by the inertia of the reciprocating parts. This was accomplished by a small weight on a crank at each end of the camshaft, with a similar shaft and weights symmetrically on the other side of the cylinder block. Weights are angularly spaced 180 deg. and the two shafts are geared together to rotate in opposite directions so that the resultant of the centrifugal forces on the four balance weights is a vertical rocking couple at all times balancing the engine couple.

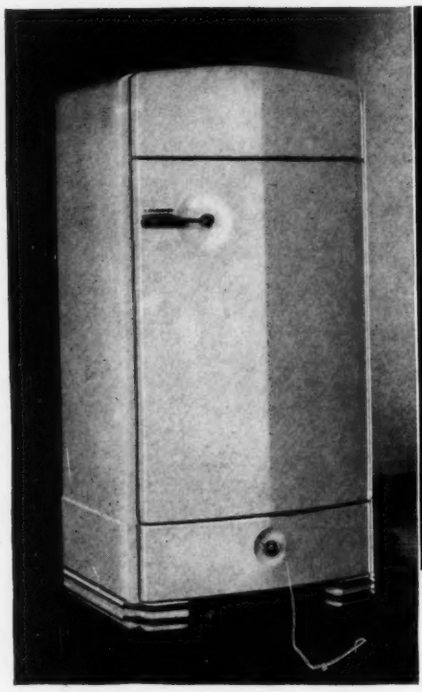
Pistons are provided with rim at top which forms a pan shaped combustion chamber shallowest at center and increasing in depth toward edge in conformity with the shape of the spray cones. Cooling ribs are provided on the underside of the piston head. A nozzle screwed into the top of the connecting rod and communicating with oil hole in connecting rod shank throws a jet of oil against underside of piston head, carrying off large part of piston heat.



Packaged power unit—General Motors one cylinder 2 cycle Diesel engine direct-connected to generator

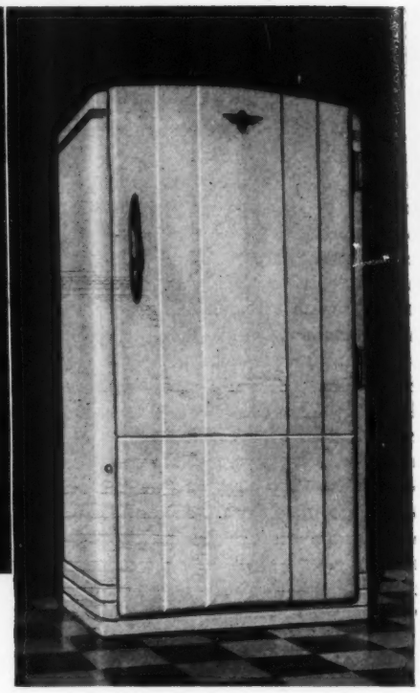


Modern Designs—Three 1938 Models in Home Equipment



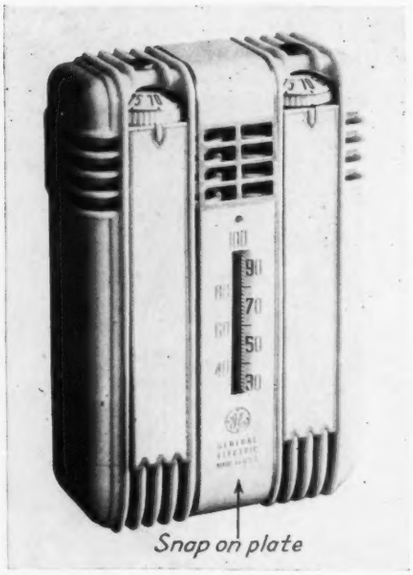
All-steel body, aluminum shelving, three interior lights and handles of Plaskon are features of new Coldspot Refrigerator, styled by Raymond Loewy for Sears-Roebuck. Storage drawer has a rubber snubber underneath for opening and closing with one's foot.

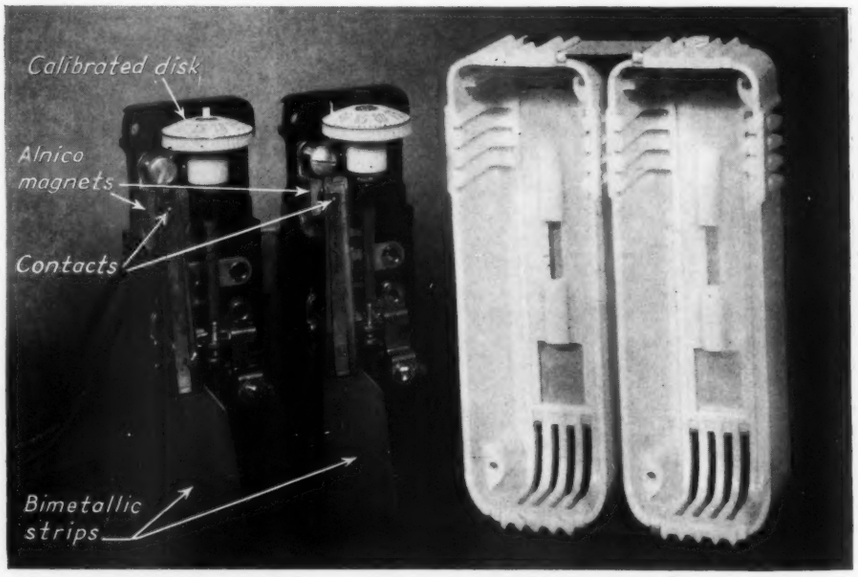
One piece "wrapper" sheet body of porcelain enamel adds to styling in new Westinghouse electric ranges by eliminating joints; it also increases rigidity and chip resistance. The "Emperor," one of ten models available, is shown here. New "Super-Oven" has two heating elements, with a porcelain enamel "Heat Evener," designed to distribute the heat currents evenly and thereby increase oven efficiency.



Modern styling in electric refrigerators combines streamlined beauty with utility. 1938 Stewart-Warner Refrigerator with a removable compartment and a shelf that pulls out and tilts downward to make articles in rear accessible, was designed by Wilbur Henry Adams.

Separate Units Designed to Look Like One



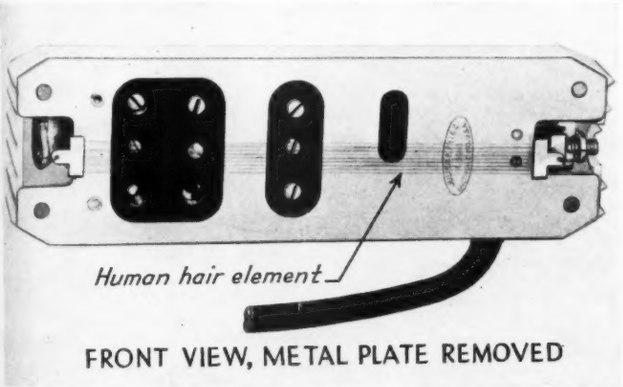


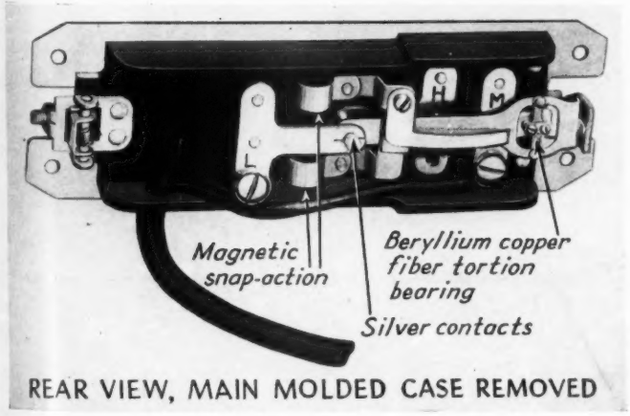
Combinations of day thermostat, night thermostat and humidistat, all of the same distinct external appearance, appear to be one unit in new General Electric design. When mounted in multiple, a snap-on plate of bronze with baked enamel finish gives the instruments the appearance of one unit. To install, the instrument is merely plugged in a wall receptacle provided in control circuit, greatly facilitating repairs and replacements. Calibrated disks for setting temperature differential are readable from horizontal or vertical point of observation.

Manually Controlled Radiator Shutters for Automobiles Back Again

Even with modern thermostatic valve control, accessory covers are often necessary on radiator grilles to cut down airflow through radiator core and thus shorten warm-up period and increase engine efficiency. New metal Winterfront, developed for 1938 Studebaker cars, mounts permanently behind radiator grille, eliminates use of auxiliary covers and provides positive temperature regulation through a manually operated dial-type dash control that permits eight selective positions of opening. Visible dial indicates amount of opening.

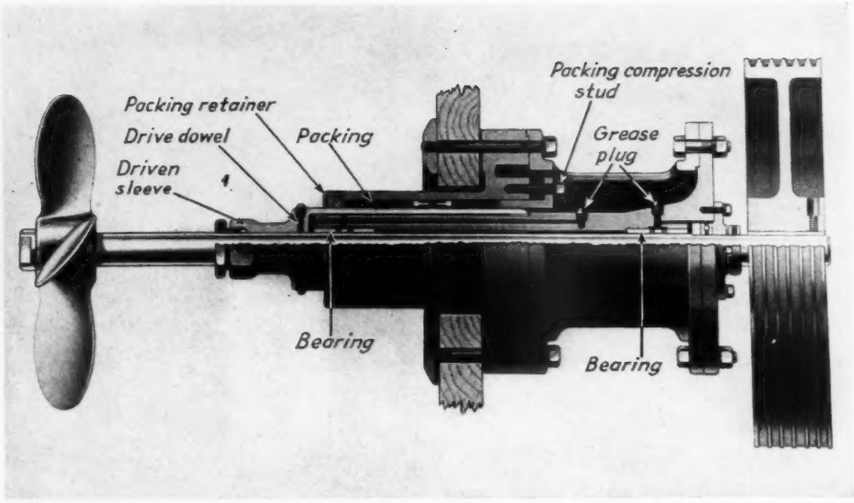
Humidistat for Mounting Against Window





Humidistat, in modern plastic housing, prevents condensation on walls and windows during winter air conditioning by keeping the relative humidity below the dew point corresponding to the window temperature. This windowstat, cased in Uralite, is held against the window by a metal bracket. Connection to the humidifier wiring system is through a polarized plug. Case molded by Consolidated Molding Products Corporation for J. P. Friez and Sons, Inc.

Modern Designs



Stuffing box has a hollow cylinder mounted on the shaft, as shown, and rotating with it. Outer surface of cylinder rotates in stuffing box, the latter having no contact with the shaft proper. Bearing member, extending into hollow cylinder from outside of tank, is thereby protected from tank liquids and stuffing box and bearings can be serviced from outside. Designed by the Mixing Equipment Co., Inc., for their new Side Entering Propeller Type Mixer.

To hold glass firmly, provide a cushioned support that would absorb shocks and vibrations, and allow for expansion and contraction was the aim of engineers of Libby-Owens-Ford in the design of the Extrudalite sash shown here. The extruded members are of 53S aluminum. Set screws run down vertically behind the glass, hold the clip lever firmly, and thereby cause the cushioning spring, shown by the dark area, to exert a definite predetermined pressure on the face piece. Thus the glass is held in place by a firm, uniformly distributed cushioned grip. Interlocking teeth in the clip and base member make the sash adjustable for different thicknesses of glass.

RANDOM JOTTINGS ABOUT NEW DEVELOPMENTS

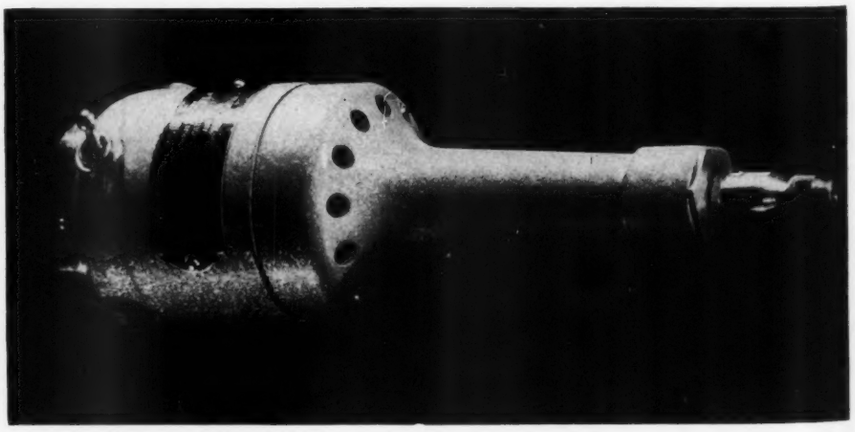
Stratosphere weather conditions—temperature, humidity, and pressure, are transmitted by short wave from a Friez Radio Meteorograph attached to a balloon. A receiver and recording instrument, located on the ground, has a radio-operated pen which records on a clock-driven chart the upper air conditions. Transmitter returns to ground by parachute.

Molded oil cans of transparent, nonbreakable plastic material, with flexible copper plated metal bottoms have been designed by Universal Plastics Corporation. Spouts, of heavy gage copper-plated material, can be unscrewed from the body as on ordinary metal cans. The amount of oil in the can is always visible through the transparent body.

Wipers made of Neoprene are now being used on the carriage wings on all Monarch lathes. Neoprene wipers, it is claimed, are not affected by oil, acids or other liquids, do not absorb grit, dirt or abrasives, and require no cleaning.

Electronic pressure-indicating tube serving as one of the resistance legs of a Wheatstone bridge circuit is used to indicate the vacuum conditions in an exhaust system. The tube bulb is connected with the exhaust system. Rate of conduction of heat from filament to bulb, which varies with amount or pressure of air in bulb, determines tube filament temperature and hence its resistance. For greatest accuracy, a second tube is used in the bridge circuit to balance out barometric pressure and ambient temperature effects. A continuous record of vacuum conditions can be had.

Claimed to be the largest and fastest in America, the mine hoist being installed by the Tennessee Coal, Iron and Railroad Company is driven by a 2,500 hp. G.E. hoist motor. Hoisting speed is 3,600 ft. per min., more than 6,000 ft. of wire rope being wound on the 18-ft. drum. Dynamic braking is used, the resistor to dissipate the heat generated weighing 30,000 lb. approximately.



Three bearing shaft, running in grease-sealed ball bearings, is used in compact, lightweight Dumore hand grinder. Universal motor of 18 hp. at 20,000 r.p.m. idling speed is controlled by operating switch built into the housing. Leads can be furnished with a third wire for grounding tool. Cooling air is drawn by a fan on the motor shaft through a filter built into the end cap. Gray crackle enamel finish adds to the appearance of the unit.

LEVER-CRANK LINKAGE

Analytical Determination of Link Velocities

WILLIAM H. RASCHE
Virginia Polytechnic Institute

A method of analyzing velocity relations in the lever-crank linkage particularly when it is employed as a quick-return mechanism and also a statement of Grashof's criteria

THE LEVER-CRANK linkage, such as shown in Fig. 1, is used in so many machines, and so little textbook space has been devoted to mathematical methods for calculating the positions of the links in reference to each other and their relative angular velocities it is likely that engineers and designers will find this discussion of value when design problems are encountered which demand a solution that is more accurate than can be obtained with graphical methods.

1. To Obtain an Exact Algebraic Expression for the Relation Between θ and ϕ—Produce the centerline of crank 2 in Fig. 1 to intersect the centerline of lever 4 at point 13. Then from the properties of triangle $\overline{14,13,12}$ the angle between these two centerlines is $(\theta - \phi)$. Let ψ designate the angle between the centerline of connecting-rod 3 and the centerline of lever 4; let *A*, *B*, *C* and *D* designate the four joints 14, 34, 23, 12, respectively; and let *a*, *b*, *c* and *d* designate the lengths of crank 2, connecting-rod 3, lever 4, and base-link 1, respectively. Then orthographically projecting *d*, *a* and *b* on *AB*, the following relation is derived,

$$c = AF + FG + GB = d\cos\phi + a\cos(\theta-\phi) + b\cos\psi \qquad (1)$$

From triangle *ABC*, moreover,

$$f^2 = b^2 + c^2 - 2bc\cos\psi \qquad (2)$$

and from triangle *ADC*

$$f^2 = a^2 + d^2 + 2ad\cos\theta \qquad (3)$$

Therefore, Equations (2) and (3),

$$\cos\psi = \frac{b^2+c^2-(a^2+d^2+2ad\cos\theta)}{2bc} \qquad (4)$$

By eliminating $\cos\psi$ from Equation (1) with the aid of Equation (4) and clearing of fractions,

$$2ac\cos(\theta-\phi) + 2cd\cos\phi - 2ad\cos\theta + b^2 - a^2 - c^2 - d^2 = 0 \qquad (5)$$

which is the desired relation between θ and ϕ.

2. To obtain the exact expression for Angular Velocity Ratio N_{21}/N_{41}—Differentiating Equation (5) with respect to time, and noting that

$$\frac{d\theta}{dt} = 2\pi N_{21}$$

and

$$\frac{d\phi}{dt} = 2\pi N_{41}$$

the following is obtained after a few simple algebraic operations

$$\frac{\frac{d\theta}{dt}}{\frac{d\phi}{dt}} = \frac{N_{21}}{N_{41}} = \frac{ac\sin(\theta-\phi) - cd\sin\phi}{ac\sin(\theta-\phi) - ad\sin\theta} \qquad (6)$$

which is the desired expression for the angular velocity ratio N_{21}/N_{41}.

For any assumed value of θ the corresponding value of ϕ can be found with the help of Equation (5), and then,

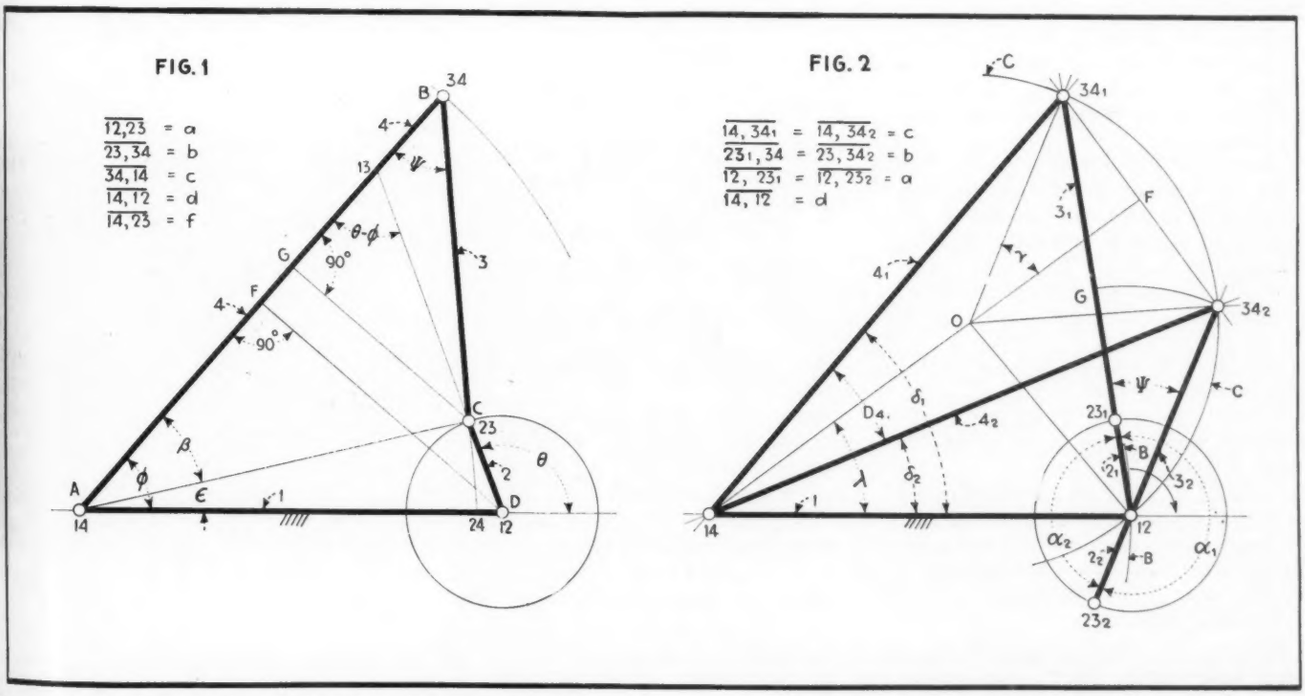


Fig. 1—Four-link lever-crank linkage diagram for studying relative velocities and deriving algebraic expressions

Fig. 2—Extreme configurations of the four-link lever-crank linkage as a quick-return mechanism

θ and ϕ being known, the numerical value of the ratio N_{21}/N_{41} can be calculated with Equation (6) to whatever degree of accuracy is desired.

But while there is no insuperable difficulty in using Equation (5) to calculate one of the variables when the other is given, this equation is somewhat cumbersome and tedious to handle. Fortunately, there is a very easy and satisfactory way to avoid its use.

To show this let

$$2S_1 = a + d + f \tag{7}$$

and $$2S_2 = b + c + f \tag{8}$$

Then for triangle ACD the well-known trigonometric formulas are

$$f = \sqrt{a^2+d^2+2\,ad\cos\theta} \tag{9}$$

and

$$\cos\frac{\epsilon}{2} = \sqrt{\frac{S_1\,(S_1-a)}{df}} \tag{10}$$

and for triangle ABC the formula

$$\cos\frac{\beta}{2} = \sqrt{\frac{S_2\,(S_2-b)}{cf}} \tag{11}$$

With Equations (9), (10), and (11) it is easy to calculate angles ϵ and β and then angle ϕ from the relation

$$\phi = \epsilon + \beta \tag{12}$$

In using Equation (12) to calculate ϕ it is necessary to observe that in the lever-crank linkage β is positive for all values of θ, also that ϵ is positive for values of θ between 0 and 180 deg. and negative for all values of θ between 180 and 360-degrees.

3. The Grashof Rules—Rules for determining whether in any case the 4-link linkage is a lever-crank linkage, a double-lever linkage, or a double-crank linkage are as follows. Any reader who may be unfamiliar with them can easily test their correctness on his drawing board.

Rule I—If the length of the longest link plus the length of the shortest link is equal to or less than the sum of the lengths of the other two links, then the linkage is

(a) A lever-crank linkage if either of the links adjacent to the shortest link is fixed;

(b) A double-crank linkage if the shortest link is fixed;

(c) A double-lever linkage if the link opposite to the shortest link is fixed.

Rule II—If the length of the longest link plus the length of the shortest link is greater than the sum of the lengths of the other two links the linkage is a double-lever linkage whichever one of the links is fixed.

These rules were formulated many years ago—nearly seventy, perhaps—by the distinguished German engineer and teacher of engineering, Professor Franz Grashof, but notwithstanding their evident value one looks in vain for them in American or English textbooks on mechanism. In Burmester's "Lehrbuch der Kinematik," pp. 283-287, can be found a most interesting and conclusive proof of their correctness.

4. The Lever-Crank Linkage Used as a Quick-Return Mechanism—A little study of Fig. 2, which shows the linkage in its two extreme configurations, will make clear the principles needed in determining the ratio of the times of the forward stroke and return stroke when this linkage is used for a quick-return mechanism.

From Fig. 2 it is evident: (1) that while crank 2 turns clockwise about axis 12 from position 2_1 to position 2_2, through angle α_1, lever 4 swings clockwise (or forward) about axis 14 through angle D_{41}; (2) that while crank 2 turns further clockwise from position 2_2 back to position 2_1, whence it started, through angle α_2, lever 4 swings counter-clockwise (or backward) through angle D_{41}; (3) and that, if the crank revolves with constant angular velocity, the ratio of the time of the forward stroke of lever 4 to the time of the return stroke of this lever is equal to α_1/α_2; that is,

$$\frac{T_f}{T_r} = \frac{\alpha_1}{\alpha_2} = \frac{\alpha_1}{360^\circ - \alpha_1} \tag{13}$$

where T_f is the time of the forward stroke and T_r the time of the return stroke. Solving Equation (13) for α_1,

$$\alpha_1 = \frac{360^\circ\,T_f}{T_f+T_r} = \frac{360^\circ}{1+\dfrac{T_r}{T_f}} \tag{14}$$

which, since (from Fig. 2)

$$\alpha_1 = 180^\circ + \psi \tag{15}$$

gives the relation

$$\psi = 180^\circ\left(\frac{T_f}{T_r}-1\right)\Big/\left(\frac{T_f}{T_r}+1\right) \tag{16}$$

an equation with which ψ can be computed when the ratio of the times of the two strokes is known.

It is also evident from Fig. 2 that

$$\overline{12,34_1} - \overline{(12,34_2)} = 2\,\overline{(12,23_1)},$$

$$\frac{\overline{12,34_1} - \overline{12,34_2}}{2} = \overline{12,23_1}$$

$$= \text{length of crank} \tag{17}$$

As a quick return mechanism it is necessary to consider five cases. In each of these cases let

a = length of crank 2;
b = length of connecting rod 3;
c = length of lever 4;
d = length of center distance $\overline{14,12}$;
D_{41} = the angle through which lever 4 swings for each rotation of crank 2; and
ψ = the angle between the two extreme positions of connecting rod 3.

Case I—Given c, d, D_{41}, T_f/T_r, and the position of center 14; required a, b, and the position of center 12.

Case II—Given a, b, D_{41}, T_f/T_r, and the position of center 12; required c, d, and position of center 14.

Case III—Given a, c, T_f/T_r, D_{41}, and the position of center 14; required b, d, and the position of center 12.

Case IV—Given b, c, T_f/T_r, D_{41}; required a and d and the relative positions of centers 14 and 12.

Case V—Given a, d, T_f/T_r, D_{41}; required b and c.

Case I—Geometrical Solution. (1) Choose the position of center 14, Fig. 2, and through it draw two lines 4_1 and 4_2, making with each other the given angle D_{41}; (2) on each of these lines lay off from 14 the given length c, thus determining points 34_1 and 34_2; (3) through points 34_1 and 34_2 describe a circle C, whose center is O on the bisector of angle D_{41}, such that one-half arc $\overset{\frown}{34_1\,34_2}$ on it will measure the angle ψ given by Equation (16); (4) from 14 as a center, with center-distance d as a radius, strike arc B, cutting circle C at 12, the required center; (5) with Equation (17) find a, the length of the crank; (6) from $\overline{12,34_1}$ subtract the length of the crank and thus obtain b.

Case I—Analytical Solution. Produce $\overline{O,14}$, the bisector of angle D_{41}, to cut $\overline{34_1,34_2}$ at F. Join O to 34_1, to 34_2, and to 12. Then angle γ in triangle $\overline{O,34_1,F}$ is equal to angle ψ in triangle $\overline{12,34_1,34_2}$ because both are measured by one-half of arc $\overset{\frown}{34_1,34_2}$ on circle C. From right-angle triangle $\overline{14,34_1,F}$ is obtained

$$\overline{34_1,F} = \overline{14,34_1}\sin\left(\frac{D_{41}}{2}\right)$$

$$= c\sin\left(\frac{D_{41}}{2}\right) \tag{18}$$

and

$$\overline{14,F} = c\cos\left(\frac{D_{41}}{2}\right) \tag{19}$$

From right-angle triangle $\overline{O,F,34_1}$,

$$\overline{O,34_1} = \frac{\overline{34_1,F}}{\sin\gamma}$$

$$= \frac{c\sin\left(\dfrac{D_{41}}{2}\right)}{\sin\psi} = \overline{O,12} \tag{20}$$

Also

$$OF = \overline{(O,34_1)}\cos\gamma$$

$$= \frac{c\sin\left(\dfrac{D_{41}}{2}\right)}{\sin\psi}(\cos\psi)$$

$$= c\sin\left(\frac{D_{41}}{2}\right)(\cot\psi) \tag{21}$$

and

$$\overline{14,O} = \overline{(14,F)} - OF$$

$$= c\cos\left(\frac{D_{41}}{2}\right) - c\sin\left(\frac{D_{41}}{2}\right)\cot\psi \tag{22}$$

The three sides of triangle $\overline{14,O,12}$ are thus known; side $\overline{14,O}$ from Equation (22), side $\overline{O,12}$ from Equation (20), and side $\overline{14,12}$ by hypothesis.

For the sake of convenience in making the rest of the analysis for this case, let

$$\overline{14,O} = e \qquad \overline{O,12} = r$$
$$\overline{14,12} = d \qquad e + d + r = 2S$$

then by a well-known formula in trigonometry with which the angles of a triangle can be found when the sides are known, applied to triangle $\overline{14,O,12}$,

$$\sin \frac{\lambda}{2} = \sqrt{\frac{(S-e)\,(S-d)}{de}} \qquad (23)$$

Thus angle λ becomes known, and thus also angles δ_1 and δ_2 of triangles $\overline{14,34_1,12}$ and $\overline{14,34_2,12}$, since

$$\delta_1 = \lambda + \left(\frac{D_{41}}{2}\right) \qquad (24)$$

$$\delta_2 = \lambda - \left(\frac{D_{41}}{2}\right) \qquad (25)$$

From triangle $\overline{14,34_1,12}$

$$\overline{34_1,12} = b+a = \sqrt{c^2+d^2-2cd\cos\delta_1} \qquad (26)$$

and from triangle $\overline{14,34_2,12}$

$$\overline{34_2,12} = b-a = \sqrt{c^2+d^2-2cd\cos\delta_2} \qquad (27)$$

Hence a and b, the required lengths of the crank and the connecting rod, respectively, are known.

Case II—Geometrical Solution. (1) Choose the position of center 12, Fig. 3, and through it draw two lines making with each other the angle ψ determined with Equation (16); (2) on one of these lines lay off from 12 a length $b + a$, on the other a length $b - a$, thus locating points 34_1 and 34_2; (3) draw the perpendicular bisector, $\overline{F,14}$, of segment $\overline{34_2,34_1}$; (4) through point 34_1 draw a line $\overline{34_1,14}$ making with segment $\overline{34_2,34_1}$ the angle $\left(90° - \frac{D_{41}}{2}\right)$; then the point in which this line cuts line $\overline{F,14}$ is center 14, $\overline{14,34_1}$ is c, the length of lever 4, and $\overline{14,12}$ is the length of center-distance.

If, however, the angle $\frac{D_{41}}{2}$ is small the preceding construction, while geometrically correct, will not locate center 14 with sufficient practical accuracy. In this case, therefore, it is better to find center 14 and the length of lever 4 as follows:

Through points 34_1 and 34_2 describe a circle, C', whose center is on bisector $\overline{F,14}$ at O', such that one-half arc $\overline{34_1,34_2}$ on it will measure angle D_{41}; the point in which this circle cuts bisector $\overline{14,F}$ is point 14, and $\overline{14,34_1}$ is c, the length of lever 4.

Center O' of circle C', can be located by drawing a line, not shown, through point 34_1 making with $\overline{34_1,34_2}$ an angle $(90° - D_{41})$ and finding the point in which this line cuts the bisector $\overline{14,F}$.

Analytical Solution. From triangle $\overline{12,\ 34_1,\ 34_2}$ is easily established that

$$\overline{34_1,34_2} = \sqrt{(b+a)^2+(b-a)^2-2\,(b+a)\,(b-a)\cos\psi} \qquad (28)$$

and from triangle $\overline{14,\ 34_1,\ 34_2}$

$$C = \frac{\overline{34_1,34_2}}{2\sin\frac{D_{41}}{2}}$$

For convenience let

$$m = \overline{34_1,34_2}$$
$$n = \overline{12,34_1} = b+a$$
$$p = \overline{12,34_2} = b-a$$
$$m+n+p = 2U$$

then from the same triangle

$$\sin\frac{\epsilon}{2} = \sqrt{\frac{(U-m)\,(U-n)}{mn}} \qquad (29)$$

thus angle ϵ is known. Moreover, from the figure

$$\beta_1 = \left(90° - \frac{D_{41}}{2}\right) - \epsilon \qquad (30)$$

Finally, from triangle $\overline{14,34_1,12}$

$$\overline{14,12} = d = \sqrt{c^2+(a+b)^2-2c\,(a+b)\cos\beta_1} \qquad (31)$$

Case III—Geometrical Solution. (1) Through center 14, which locate in any convenient position, draw lines 4_1 and 4_2, Fig. 4, making with each other the given angle D_{41}, and on each of them

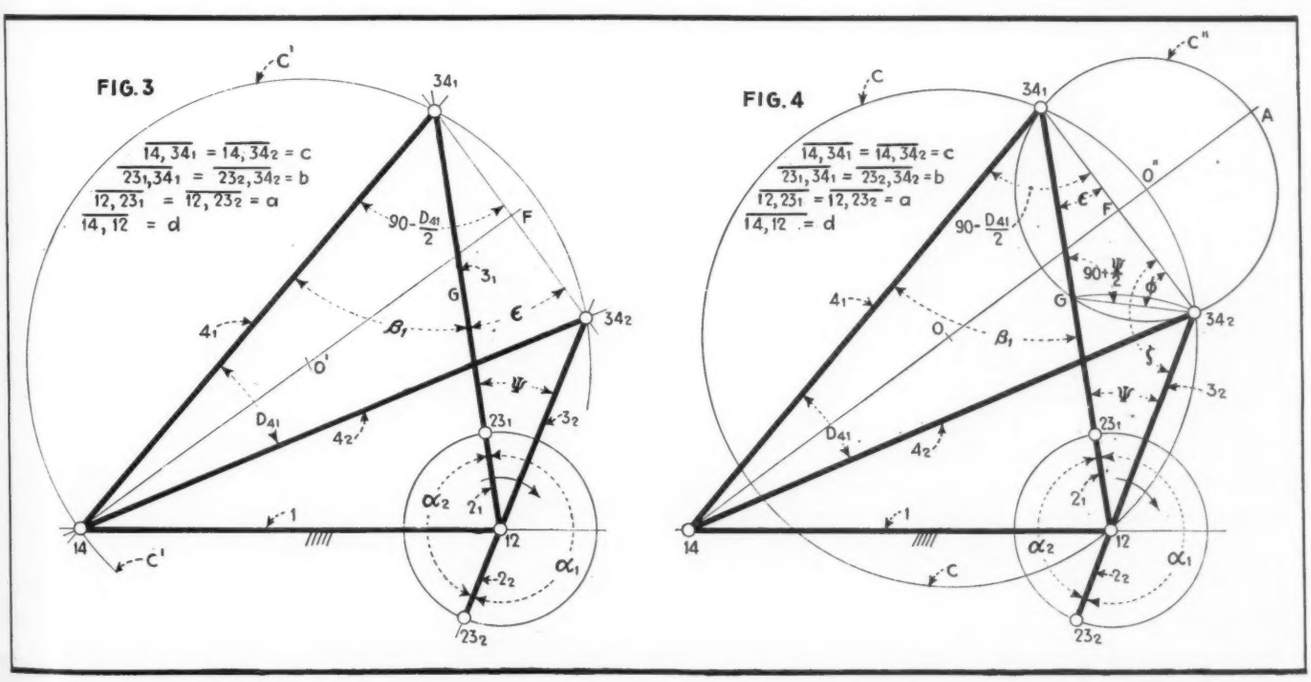


Fig. 3 — Construction diagram for finding the length of lever 4, center-distance d and position of center 14

Fig. 4—Construction diagram for finding the length of connecting rod 3, center-distance d and position of center 12

lay off from 14 a length c, thus locating the extreme positions, 34_1 and 34_2, of lever-pin 34; (2) with Equation (16) calculate angle ψ; (3) through points 34_1 and 34_2 describe circle C'', whose center is O'' on bisector $\overline{14, F}$, such that one-half of arc $\overline{34_1, A, 34_2}$ on it will measure the angle $\left(90° + \frac{\psi}{2}\right)$. (4) from 34_1 as a center with a radius $2a$, twice the given length of the crank, strike an arc cutting circle C'' at point G; (5) through points 34_1 and 34_2 describe a second circle, C, whose center is on bisector $\overline{14, F}$ at O, such that one-half of arc $\overline{34_1, 34_2}$ on it will measure angle ψ; (6) join points 34_1 and G and produce line $\overline{34_1, G}$ to cut circle C at the required center 12 and so find $\overline{14,12}$ the required center distance d; (7) subtract a, the length of the crank, from $\overline{34_1,12} = (a + b)$ and thus find b, the length of the connecting rod.

Notes: 1. Center O'' of circle C'' is, of course, the point of intersection of circle C and bisector $\overline{14, F}$.

2. Triangle $\overline{34_2, G, 12}$ is isosceles; therefore the angle at G in triangle $\overline{34_1, G, 34_2}$ is $90° + \frac{\psi}{2}$

Analytical Solution. From isosceles triangle $\overline{14, 34_1, 34_2}$

$$\overline{34_1, 34_2} = 2c \sin\left(\frac{D_{41}}{2}\right) \quad (32)$$

From triangle $\overline{34_1, G, 34_2}$, by the law of sines,

$$\frac{\sin\phi}{\sin\left(90° + \frac{\psi}{2}\right)} = \frac{2a}{2c \sin\left(\frac{D_{41}}{2}\right)} = \frac{a}{c \sin\left(\frac{D_{41}}{2}\right)},$$

that is,

$$\sin\phi = \frac{a}{c \sin\left(\frac{D_{41}}{2}\right)} \cos\left(\frac{\psi}{2}\right); \quad (33)$$

thus angle ϕ becomes known. Moreover, since

$$\zeta = \left(90° - \frac{\psi}{2}\right) + \phi \quad (34)$$

ζ also becomes known.

Now from triangle $\overline{34_1, 12, 34_2}$, by the laws of sines

$$\overline{34_1, 12} = a+b = \left(\frac{\sin\zeta}{\sin\psi}\right) 2c \sin\left(\frac{D_{41}}{2}\right) \quad (35)$$

thus $(a + b)$, and therefore also b becomes known.

From triangle $\overline{34_1, G, 34_2}$

$$\epsilon = 180° - \left\{\left(90° + \frac{\psi}{2}\right) + \phi\right\} \quad (36)$$

Obviously, moreover,

$$\beta_1 = \left(90° - \frac{D_{41}}{2}\right) - \epsilon \quad (37)$$

therefore β_1, of triangle $\overline{14, 34_1, 12}$ is known, and thus also from the same triangle, by the law of cosines,

$$\overline{14, 12} = d = \sqrt{c^2 + (a+b)^2 - 2c\,(a+b)\cos\beta_1} \quad (38)$$

giving d, the required center distance.

Case IV—Geometrical Solution. There is no ruler-compass solution to this case, at least the writer has not succeeded in finding one, but a very good graphical construction is available.

(1) Choose the position of center 14, Fig. 5, and locate points 34_1 and 34_2 just as for Case I; (2) plot, near the probable position of center 12, a small portion of an ellipse, E_{12}, whose foci are 34_1 and 34_2 and whose long diameter is $2b$, twice the given length of the connecting rod; (3) draw circle C as it was drawn for Case I. The point of intersection of ellipse, E_{12} and circle C is center 12, and $\overline{12, 14}$ is the required center distance d; moreover,

$$a = \frac{\overline{12, 34_1} - \overline{12, 34_2}}{2} = \frac{(b+a)-(b-a)}{2} \quad (39)$$

Note: That the locus of center 12 is an ellipse whose foci are 34_1 and 34_2 and long diameter is $2b$, it follows that

$$\overline{12, 34_1} + \overline{12, 34_2} = (b+a)+(b-a) = 2b \quad (40)$$

Analytical Solution. From triangles $\overline{12, 34_1, 34_2}$ and $\overline{14, 34_1, 34_2}$, Fig. 5,

$$4c^2 \sin^2\left(\frac{D_{41}}{2}\right) = (b+a)^2 + (b-a)^2 - 2(b+a)\,(b-a)\cos\psi \quad (41)$$

which being solved for a gives

$$a = \sqrt{\frac{2c^2 \sin^2\left(\frac{D_{41}}{2}\right) - b^2\,(1-\cos\psi)}{1+\cos\psi}} \quad (42)$$

Moreover, also, formulas (29), (30), and (31), Case II,

$$d = \sqrt{c^2 + (a+b)^2 - 2c(a+b)\cos\beta_1} \quad (43)$$

Case V—Geometrical Solution. There is, so far as the writer knows, no ruler-compass solution of this case either; moreover, there does not seem to be a good graphical construction for it. There is a graphical construction but it is tedious to execute and does not give very accurate results.

Analytical Solution. Assume a reasonable value for b, one of the required quantities, and compute a trial value for c with Equation (41), Case IV. Then use Equations (29), (30), and (31), Case II, to compute a trial value for d. Compare this trial value of d with the given value of this quantity. If the two values are not in sufficiently close agreement, choose another value of b and recompute d. Continue this process until the trial value of d agrees with the given value with sufficient exactness for the purposes of the design. When the agreement is finally sufficiently close, the corresponding values of b and c will be the required values of these quantities.

There are formulas for this case with which b and c can be computed without trial, but they are too complicated and unwieldy to be of service in practice. The trial-and-error method explained in the preceding paragraph, despite its tediousness, is much better.

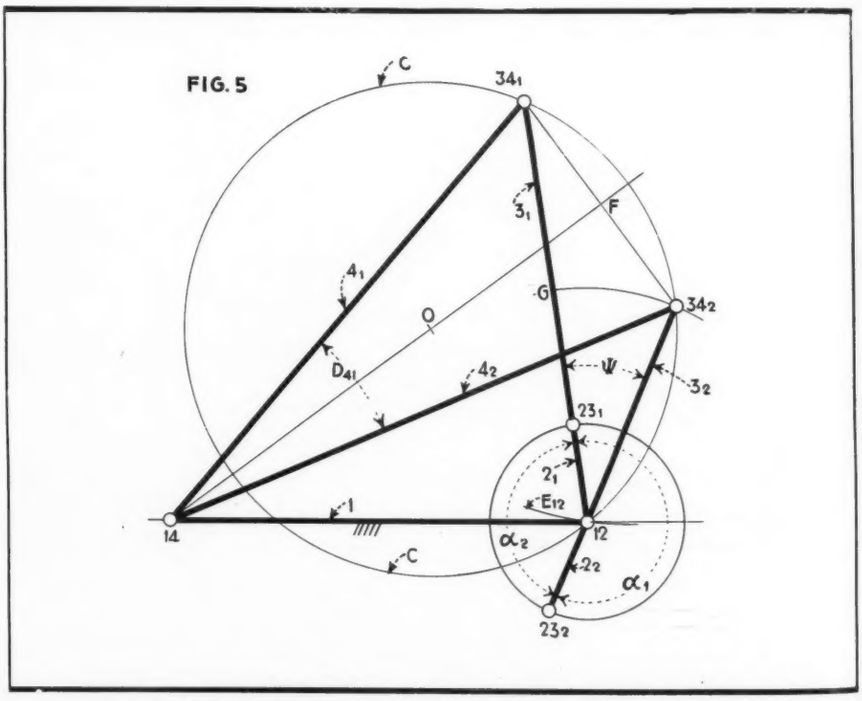
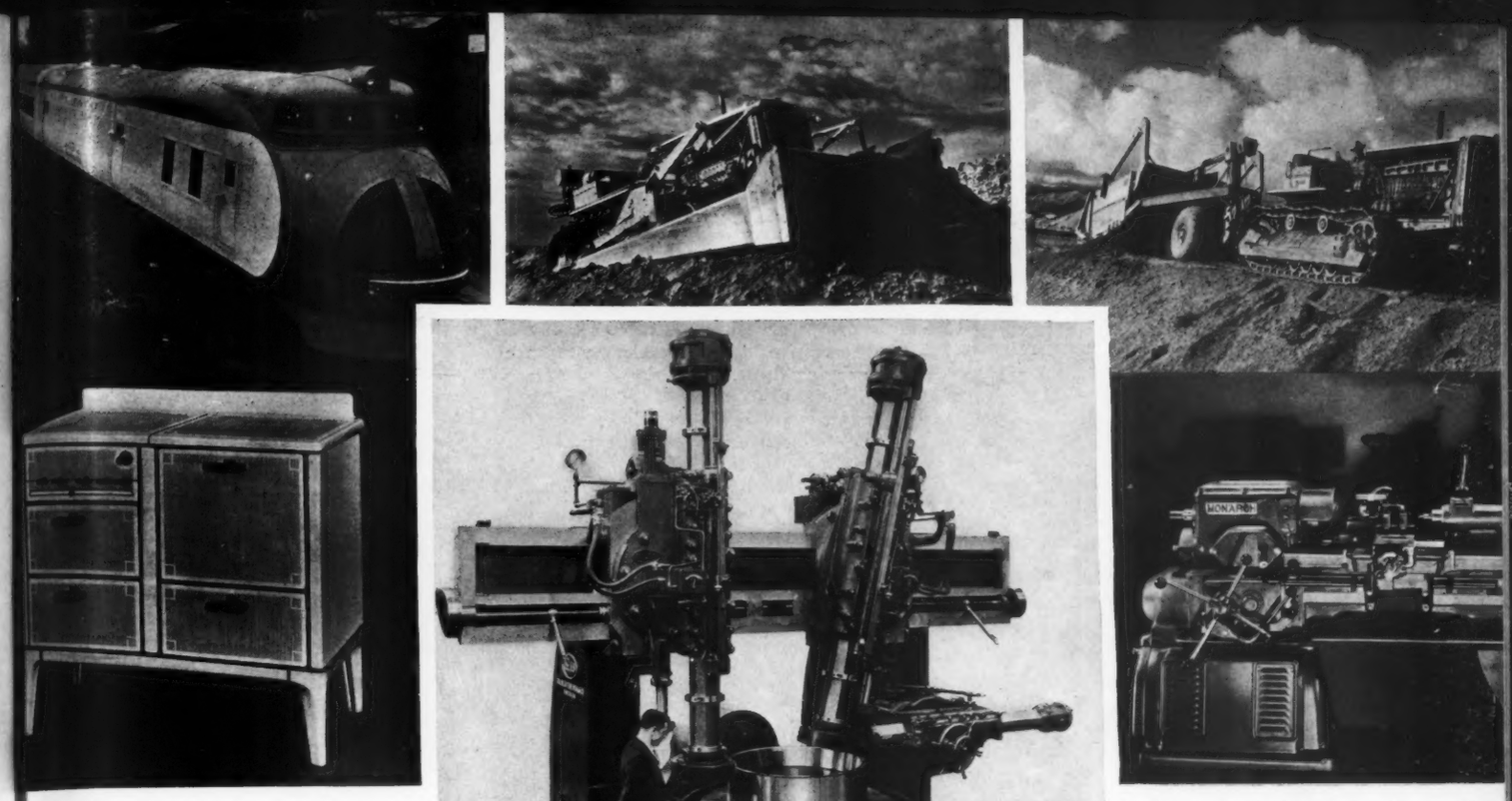


Fig. 5—Construction diagram for finding the length of crank 2 and center-distance d when other data are known



Designed during the 1930 depression, these products not only led the way back to prosperity but also made money for their manufacturers

NEW-PRODUCTS PROGRAMS

A Survey of the Status of Design Activity

G. F. NORDENHOLT, *EDITOR*

Statements by company officials bear out the impression that aggressive development programs are pursued irrespective of the general state of business

WHAT'S the other fellow doing? That question crops up every time an out-of-the-ordinary situation develops. Not long ago I was discussing with the vice-president of a medium-size manufacturing company product development activities during depressions. I expressed the opinion that progressive companies keep up their research and development programs regardless of the state of business. I even went further and claimed that most progressive companies devote more time and attention to the development of new or improved products during times of depression than they do during periods when business is brisk. To my mind, this was only logical because when business is slack, the engineering department is able to give more time and undivided attention to the development of new products. He did not agree with me.

"That is a very feasible theory," he said, "but like most theories in business, it is only partially true and not very much so at that. Read the Department of Labor employment figures relating to engineers and the depression. In plain english, the engineering companies during the late major depression kept their engineering staff together as long as they could see a little commercial daylight ahead of them and when the commercial sun ceased to shine, they fired them. The records of the engineering societies' employment bureaus also prove that.

"New engineering designs that are worth while are evolved during the periods of greatest business activity, when customers are submitting their problems by the scores, and the manufacturer can afford to employ an adequate engineering staff. It is true that some refinements of designs are made during the early part of a depression when customer pressure is relaxed. But you will recollect that quite a few manufacturers emerged from the last depression with hoary relics in the way of designs, at which the Curator of the Smithsonian looked with hungry eyes."

"That's something to think about, Bob," was my reply. "But getting down to cases, as vice-president of your company, you know not only what is being done now in the way of new engineering designs, but also the plans for the immediate future. How does your company stand?"

"We expect this to be a short depression," he replied. "Hence we breathe freely in an engineering way. In fact, we have expanded our engineering force, but if this depression lasts long enough, we will eventually follow the same course as that which will be followed by 99.9 per cent of all other manufacturers and reluctantly let out those trained engineers whom we cannot afford to continue to employ, which is sad but true."

"Don't you think that it would be more profitable in the end to maintain your engineering staff?" I asked.

"Of course, I do," was the answer. "But unfortunately, many manufacturers have not learned to save pennies.

And when they do, they should have a compartment in their money box to hold a few pennies wherewith to keep together the engineering force during a depression and thereby combat the weeds and profits-destroying fungus of deteriorated designs. But the fact is, few companies spend much for research during a depression."

Millions for Research

Realizing the futility of discussing or arguing a question of fact, I decided to do a little investigating and find out about engineering activity in large, small and medium-sized companies. The first thing that I came across was the statement of Lammot duPont, president of E. I. duPont de Nemours & Company, in his annual report to stockholders published early in February.

According to Lammot duPont, twelve products, developed largely during the last ten years, accounted for about 40 per cent of the total sales volume of the duPont company for the year 1937. These products included Duco lacquer, Dulux enamel, development of which started in 1930, neoprene–chloroprene rubber in 1932, synthetic camphor developed in 1933 and various chemicals developed in 1935. With reference to the research and development activities during the period from 1930 to 1936, the average yearly expenditure since 1929 has been more than $5,000,000 per year, this not including considerable additional sums spent for improving processes. In 1936, the expenditure for research and product development activities was $6,500,000, and 1937 showed no slackening. Quoting Lammot duPont, "As in past years the company continues its comprehensive research program, and generous provisions were made in facilities and specialized personnel to the end that the company's products continue their position in the forefront of industry. The company's policy calls for continuance (during 1938) of this program."

Of course, the duPont company is a highly specialized company and a large corporation. Here is what the vice-president of a medium-sized machine tool builder wrote us:

"In times of depression, our company has devoted much more time and attention to engineering design development and the development of new and improved products. During the period of 1930 to 1934 our company introduced many more new features and new developments than we did in the very active years of 1926 to 1929. At the present time our company is pursuing a very aggressive development program which we have every intention of continuing irrespective of the general state of business.

"It is true that as business slacks off our engineering department is able to give more time and attention to development work, although it has been our policy, as much as possible, to have a separate development division which is not directly affected by the state of business."

The chief engineer of another machine tool builder stated:

"It is not entirely true with us that the more extensive design developments take place during depression periods. It is true that during 1930 and 1933, we introduced an entirely new line of machines, but the design of this line covered quite a number of years prior to the time they were introduced. And during the period of 1936 and 1937 we were again extremely active in developing new machines and special machines. But at the present time we are less active in designing than we have been for a long time. And we are using this period for refining and coordinating our current products. Also we are putting our tracings and records in the best possible form."

This chief engineer definitely states that he is "using this period for refining and coordinating our current products." From this I concluded that he was taking advantage of the lull to improve his designs with reference to details, a conclusion which I verified.

Engineers Added to Staff

Quoting the president of another machine tool manufacturing company:

"We did a certain amount of development work during the depression, but not as much as we should have, inasmuch as it was necessary to conserve our resources. However, our complete line of drills has been redesigned since 1928 and we are going to find it necessary to start a new program of redesign in the very near future.

"We are making at the present time some additions to our engineering department as well as to our office in order to take care of what we think is going to be, and hope will be, an increasing amount of business. We have several projects that we want to further when the opportunity presents itself."

But how about companies other than machine tool builders? Here's what the chief engineer of the world's largest manufacturer of power garment presses writes:

"I believe that generally speaking, organizations engaged in the design and manufacture of machinery, and for that matter any article, increased their efforts to produce new designs during periods of slack business, in order to maintain their position in the industry. Immediately after 1930 when business took a perceptible drop, we investigated the subject of cleaning garments with synthetic solvents instead of naphtha or ordinary dry cleaner. And during the worst years of the No. 1 depression, we designed such a machine.

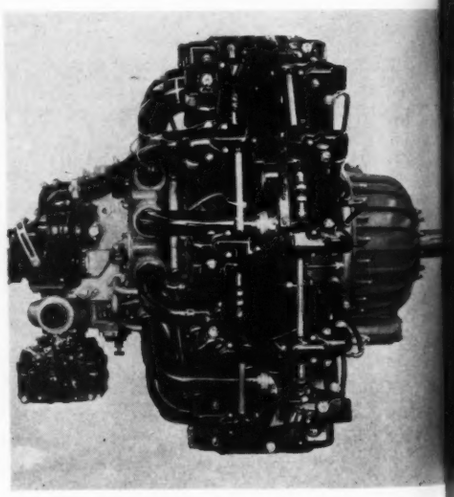
"With reference to all our developments, it appears that in the years from 1926 to 1929 the trade was satisfied to accept, and we were satisfied to continue in the manufacture of, our regular line of machines. No attempt was made to beautify these machines or to bring them up to a new standard in design or performance. Prices were satisfactory, sales numerous and there was no particular incentive to excel in development.

New Designs Make Sales

"But our company has been more active in design developments during depression years than at any other time. It is true that during the very worst years of the No. 1 depression, our engineering department, as well as all other departments, was greatly reduced. But before conditions perhaps even warranted, the engineering department was increased and new developments were undertaken and pushed forward at the highest possible speed. At this time, and all during this "new deal" depression, our engineering department is operating with about the same force as we had in 1929."

And here is what the chief engineer of a washing machine manufacturer, writes:

"It has been our policy to carry through the lean periods without restricting our engineering and development activities. There has been no reduction in the personnel of the engineering department. In fact, there has been a gradual increase over the past seven years and the engineering payroll has not fluctuated with the general factory's payroll. We have not followed the practice of laying off men who were occupied with production engineering. We retained these men and shifted them to development engineering.



"We have also employed artists to produce entirely new and striking product designs, this procedure following

closely that of the automotive industry.

"I believe that it is more important to make new developments and announce improvements in the lean periods than in the high production periods. I have noted that it is most stimulating to sales to have during hard selling periods a complete new line containing many innovations and improvements. This is precisely what our company did during October of last year with most gratifying results."

It is quite generally conceded that aeronautics has been the most progressive field in product development. Here is a statement from the assistant chief engineer of one of the leading aeronautical manufacturers:

"It is believed that our situation in the aeronautical engine industry is by no means typical of most business enterprises in that we are working in a period of intensive development and growth, characteristic of the early years of a new industry. Because of our particularly fortunate circumstances, the broadening market for our product was only slightly affected by the depression of 1930-33. For the same reason, the current difficulties are not particularly pressing. It is, therefore, obvious that our new developments and rate of progress have at the moment, but little significant relation to general business.

"Our management policy is firmly fixed in regard to the desirability of continually maintaining our basic engineering research and development activities at all hazards, and in times of stress (which we have experienced) it is our practice to effect only the most obvious economies in regard to engineering work, reserving drastic curtailment of development work to the last necessity.

"In regard to our industry, it is not true that reduced production deliveries permit an increase in the amount of attention afforded to design and new development because these two are distinctly separate in our organization. In other words, not much of our engineering attention is devoted to problems of current production, most of the activity centering around new developments."

Quoting one of the leading manufacturers of tractors and industrial engines:

"Our company does not believe in a stand-still position at any time. During the major business depression we developed and launched our first diesel-powered tractor. I don't think it is necessary for me to outline the importance of that development so far as it affects ourselves or the general public. Introduction of diesel economy into tractor operation has brought about an entirely new production cost schedule in road building, dirt moving, etc. Throughout the years 1930 to 1933 our engineers were constantly at work in developing the diesel engines and finding new applications for diesel power. The result is that we have reached a position of leadership in the industry that would not have been possible had our administration officials adopted a different policy at that time.

"You will be interested in knowing that we have just announced our new 3-4 plow size tractor with diesel power. The new engine introduces several new developments, including oil cooling. Because of the work of our engineering staff, we are able to offer this tractor at a lower price than any diesel-powered tractor has ever been offered.

"It can hardly be said that we have stimulated engineering development during the 'recession,' but we have at least maintained it on the same level as we did during the years of 1936 and 1937 which are recognized as good years. We don't believe in slowing down development of our products."

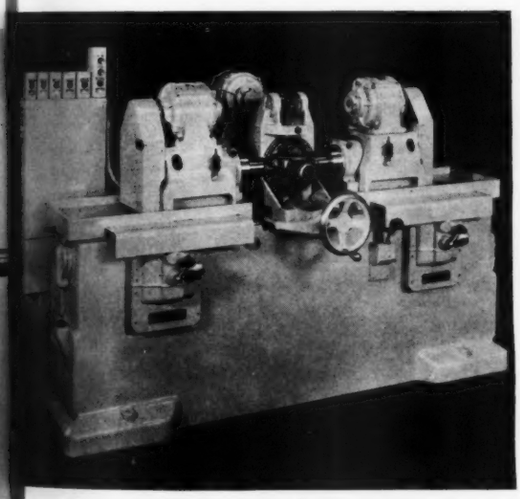
An interesting slant on the status of product development programs is furnished by Ben Nash, industrial design consultant. According to Mr. Nash:

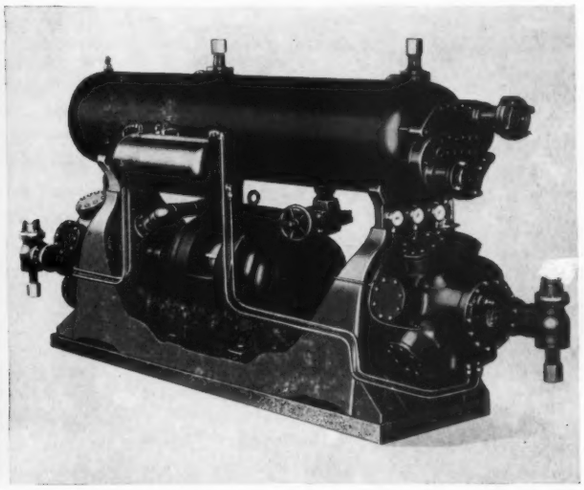
"Many of the major industrial design projects upon which we have cooperated were initiated and carried on during seemingly dull times to meet the need for doing something in product development or improvement to hold as much as possible of the current sales volume. Lull periods bring out plans and projects which had been held in abeyance or were held inactive because everyone about the organization was saturated with current sales mindedness. But when matters become more competitive these projects come out into the open for consideration and action, and because of general business inactivity they receive the major attention and cooperation of executives, thus helping to speed up the projects' completion.

"Working in this way the product or improved product is ready to be placed on the market the minute sales activity starts to return. This gives the far-sighted manufacturers an edge in building distribution and sales.

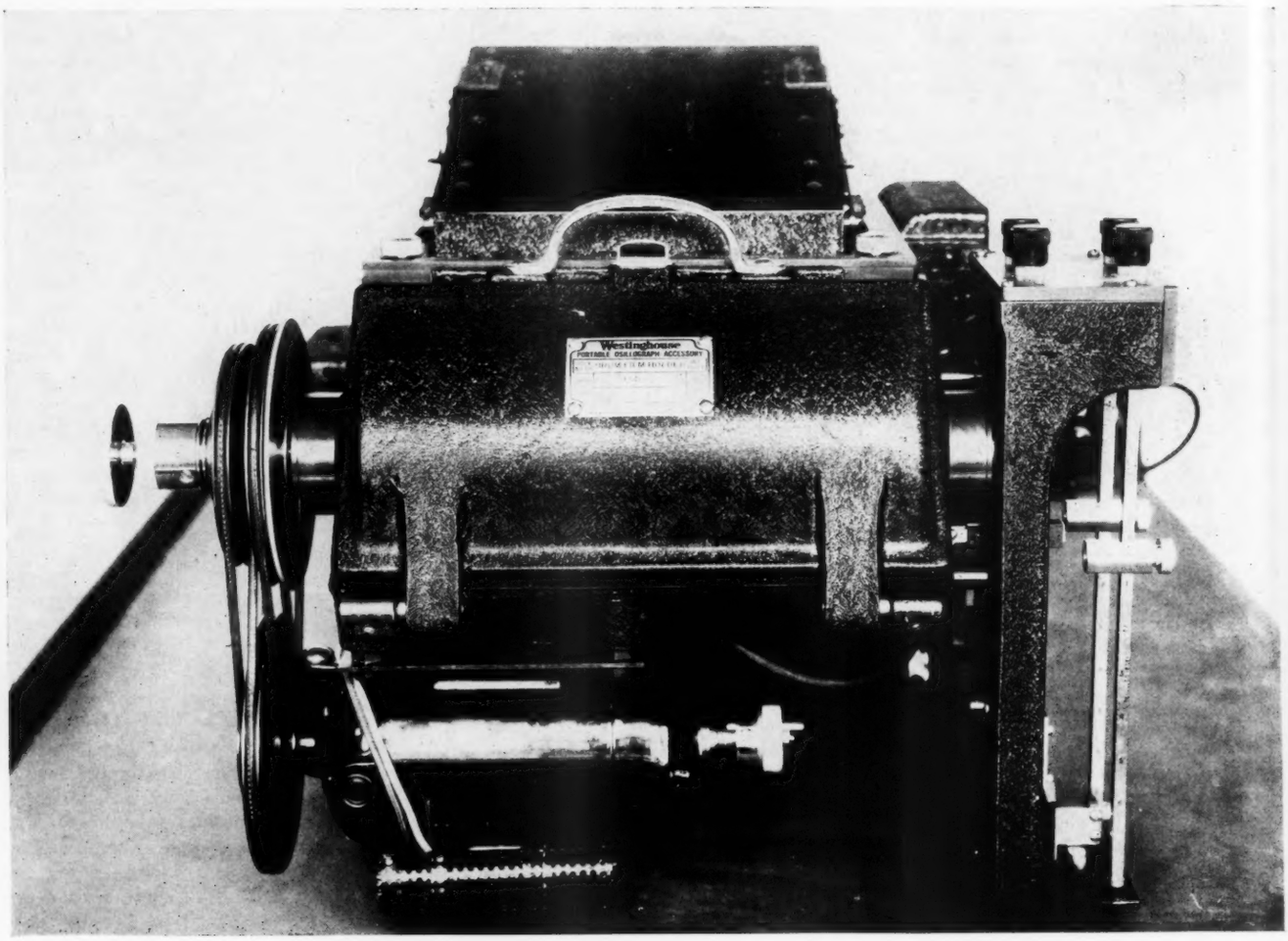
"Now, as in every business recession, if a manufacturer or his laboratory, or his engineering department, or his sales department has a new product idea or a product improvement which is believed to be good, it should be started now when everyone from top to bottom can work together to help it make good."

Space does not permit including in this article numerous other letters similar to those given above, bearing on the question of engineering activities during depression. Suffice to say, we have presented all of those that in any way suggest that product development activity is curtailed during depressions. And on the other hand, the quotations omitted all indicate definitely the undiminished continuance of products developed activities during periods of depression. Admittedly, there are some companies that cannot afford to follow out such a program, but all indications are that most companies plan their programs so that product design and development continue with a vigor that has little relation to general business.





History now repeats itself. Out of the engineering departments are coming new designs more economical to manufacture, more serviceable, better styled and easier to sell



Universal motor with Lee governor, adjustable while running, drives this oscillograph at constant and correct speed. Resistor is housed in the perforated sheet casing below the motor

SPEED-GOVERNED MOTORS

Their Operation, Applications, and Limitations

F. W. YARLINE, *BODINE ELECTRIC COMPANY*

Now developed to a high degree, governors have solved the problem of using universal motors for driving devices where speed control is required

EARLY METHODS to control the speed of universal motors used rheostats or tapped windings. (See *P. E.*, p. 46, Feb. 1938). But these methods permitted speed control only over a relatively narrow range and, what is even more important, sacrificed the starting torque at low speeds. Today, most of the automatic governors for universal motors are, in principle, centrifugal switches which cut off and restore the full current supply, or a portion thereof, to the motor. Thus, when the governor contacts are closed, the motor is operating under full line voltage and therefore performs according to its normal torque-speed curve. This explains why such a governor controlled motor has full starting torque, regardless of the speed for which the governor may be set.

The small centrifugal-switch type of governors for universal motors consists essentially of contact points in series with the motor windings. In its simplest form, centrifugal force acting upon one of the contacts and its cantilever supporting arm tends to open the contact, the centrifugal force being counteracted by a spring. A means for manually adjusting the contact points so as to cause them to open and close at different speeds is employed.

If such a switch were to cut off the current supply completely, the speed of the loaded motor would drop suddenly, causing the governor contacts to close

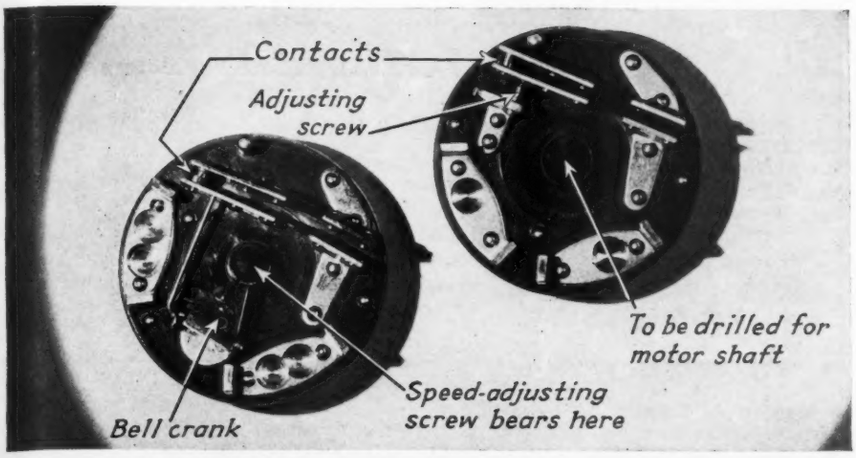


Fig. 2—Two designs of Lee governors for controlling the speed of universal motors. The upper is adjusted by the screw bearing against the lower contact arm. The other governor can be adjusted while the motor is running. A screw extending out from the end of the motor and co-axial with the shaft, bears against the end of the long arm of the bell crank, thereby positioning the small bar that bears against the contact arm

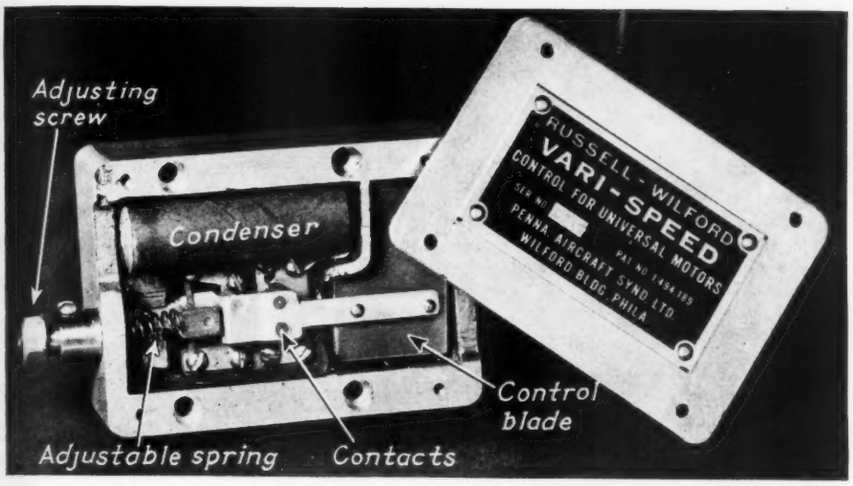


Fig. 3—The Russell-Wilford governor is mounted in the air stream from a fan mounted on the shaft of the motor. Speed variations vary the air pressure against the pivotted control vane, movement of which is opposed by the adjustable spring. No resistor is used

and restore the full current supply. Operating under the extremes of no current and full current, the motor would run jerkily. Furthermore, making and breaking the full current would impose a severe duty on the contact points, tending to burn them. Therefore, a resistance is shunted across the contact points as shown in Fig. 1. When they open, the current supply to the motor flows through the resistance, thereby being reduced correspondingly.

The resistance shunted across the governor contacts is usually a vitreous enamelled unit, its required ohms resistance being determined experimentally for the given motor when connected to the machine load it is to drive.

A condenser is also connected across the governor contacts in order to reduce to a minimum the spark when the contacts open. The required microfarads capacity of the condenser is also determined by test under working conditions after the proper size of shunt resistance has been selected and installed. The condenser capacity should be the lowest value compatible with minimum sparking at the contact points. For small appliances the condenser capacity is usually of the order of one-half microfarad.

A number of typical designs of governors for universal motors are shown in Figs. 2 and 3. They can also be used on shunt, compound and compensated series motors, but their principal field of application is on universal motors.

Of the many governors available, the one now most widely used by motor builders and appliance manufacturers alike is the Lee governor. The characteristics of this governor are particularly favorable to a wide variety of requirements. The illustrations show the construction of the governor and the manner in which it is mounted on the motor shaft. Brushes mounted parallel to the motor shaft carry the current to the governor slip rings. It is then conducted by rivets through the brackets which support the contact springs.

Governors designed to operate over a fairly narrow range of speeds have one spring for each contact. The contact is not mounted directly upon the spring, but upon a flat piece of brass strip riveted to the spring. This brass strip acts as a radiator, carrying the heat away from the governor contacts, thereby minimizing their oxidation.

On governors which must operate over wide ranges, these radiators sometimes cannot be used because the centrifugal force due to their mass would hold the contacts open long before the entire speed range was covered. For such governors, therefore, two springs are used in conjunction with the outer contact. One spring supports the contact itself, and acts during the lower portion of the speed range. The other spring parallels it, and restrains it when the higher speeds are reached.

If no radiators can be used with this type of governor, current through the governor contacts must be kept to lower limits, of the order of two amperes, if satisfactory life is to be secured.

The question of current input and governor contact materials becomes especially important as the motor voltage is lowered. There is a demand for constant speed motors to operate from low voltage storage batteries, and if these motors are to deliver an appreciable amount of power, say one-tenth horsepower, the current input must necessarily be high. For higher voltages, tungsten contact points have been found most satisfactory. But some of the oxides of this element have rather high resistance. With a high current this resistance causes a voltage drop which is a large percentage of the total voltage available. Satisfactory operation under such conditions cannot be obtained. It is a general practice, therefore, to use platinum contacts on low voltages.

The many advantages of Lee govern-

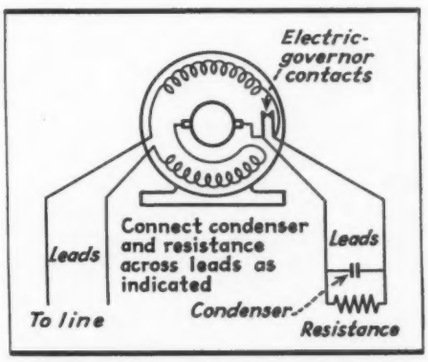


Fig. 1—Diagram of connections of a speed-control governor in a series universal motor

ors for general use include the following:

1. The governor contacts are located near the edge of the governor and the greatest amount of centrifugal force for speed and mass is thereby secured.

2. The mass of the moving parts is small, permitting rapid change of position because of the small amount of momentum which must be overcome. This favors obtaining constant motor speeds.

3. The governor springs can be furnished for a wide variety of speed requirements.

4. Governor size is small.

5. The governor can, in one type, be adjusted by means of a set screw but only when the motor is standing still and partly disassembled, or, in the other type, speed can be adjusted by an external knob control while the motor is running.

In designing a governor-controlled motor for a given application, it must be designed to develop sufficient power to drive the load at somewhat more than governed speed, proper allowance being made for the additional power required to overcome governor friction and extra windage losses.

Rapid Contact Action

When operating, the governor-controlled motor tends to run faster than the pre-set governed speed, thereby causing the governor contacts to open and compelling the current to flow through the resistance. This causes the motor speed to drop. The governor switch contacts then close, normal operating voltage is restored and the motor speeds up until the governor contacts again open. With the motor and governor correctly designed for the application, this action is extremely rapid, and no noticeable change in motor speed occurs. There may be as many as 800 interruptions per sec. on some services.

In opening and closing, the governor contacts effect a rapid transformation of the motor performance as indicated by the speed-torque curves in Fig. 4. The motor operates in effect as two motors, one weaker than the other, having different speed-torque curves. The weaker of the two motors, the one operating when the switch contacts are open, is not quite powerful enough to operate the load at its point of minimum torque requirement at the desired speed for which the governor is set. The second motor is more powerful than the first, and is strong enough to operate the load at its maximum torque requirement but at a speed in excess of the desired speed for which the governor is set. Thus, the governor transfers the load rapidly from one motor to the other, so rapidly, in fact, that the speed has no time to reach a constant value for either of the two motors, but is kept at an average value the speed for which the governor is set.

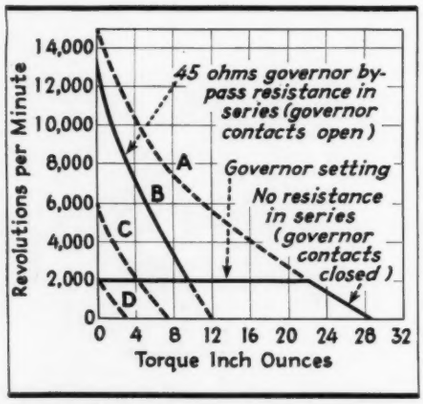


Fig. 4.—Composite speed-torque curves for an electric governor controlled motor operating on 110 volt, 60 cycle a.c. current

Torque Values

A horizontal line may be drawn between curves *A* and *B* in Fig. 4 connecting them at a speed corresponding to the average speed maintained by the governor. At the speed of 2,000 r.p.m., which in this example has been arbitrarily selected as the governor setting, this horizontal line intersects the speed-torque curve of the motor-with-resistance at about 9.5 oz.-in. torque, and intersects the speed-torque curve of the motor-without resistance at 22 oz.-in torque. Therefore, the motor has a definite range of torque values from 9.5 to 22 oz.-in. over which the speed is controlled. The load imposed by the machine must have minimum and maximum values of torque within the limits of the controlled values. Actually, the speed will begin to drop slightly before a load of 22 oz.-in. is reached, because at this point there is little reserve power available to speed up the motor. This drop in speed between minimum and maximum torque expressed as a per cent of the speed at minimum torque, is termed per cent speed regulation. Generally it is so small that it need not be considered.

It is highly desirable to keep the value of the resistance connected across the governor as low as possible, in order to bypass the maximum permissible amount of current through the resistor, and thereby avoid wear and burning of the contact points. However, it is evident from the speed torque curves in Fig. 4 that if the resistance is low, the drop in speed when the contact points open will be small, and consequently the horizontal line between curves *A* and *B* will be relatively short. This means: (1) The torque range over which effective governing can be obtained will be relatively limited; (2) The best speed regulation will be secured, and the longest life of the governor contacts will be obtained; (3) The motor will be too powerful at torques less than 9.5 oz-in., in this example, to maintain a speed of 2,000 r.p.m. and consequently the motor will operate at a considerably higher speed, as shown by curve *B* in the figure.

This high speed operation is, of course, avoided if the motor is connected to the load at all times, and the minimum load is greater than 9.5 oz.-in. If it is not, there is a definite tendency for the motor to race, and at no loads this speed may still be so high as to cause the governor to be destroyed by centrifugal force. Most types of electric governors should not run at speeds as high as 10,000 r.p.m. for this reason.

Avoiding High Speeds

For applications where high speeds under light loads are to be avoided, more resistance must be used across the governor contacts. This will result in a decrease in power of the motor when the governor contacts are held open, and, depending upon the amount of resistance inserted, will give a performance such as that indicated by curves C and *D*, in Fig. 4. It is evident that if sufficient resistance is inserted to give the performance indicated by curve *D* the motor will operate under all torque conditions at 2,000 r.p.m. assuming that the governor is set for that speed. This arrangement, however, does not permit the motor to operate at a speed of 4,000 r.p.m. If the governor contacts are to be set for that speed, the value of the resistance across the contacts must not be more than that used to secure the performance shown in curve *C*, for example.

Typical Applications of Governor Controlled Motors

They are used on:	*Principally to obtain:*
Food Mixers	**—High torque on low speeds**
Flame Cutters	**—Wide range of adjustable constant speed**
Adding Machines	**—Limitation of speed at light loads**
Portable Tools	**—Limitation of speed at light loads**
Cinema Projectors	**—Constant speed with varying voltage**
Cameras	**—Constant speed with varying voltage**
Instruments	**—Constant speed on d.c.**

The proper choice of the amount of resistance to be put across the governor contacts is one that can be determined only when both maximum and minimum value of torque required and the speed range over which the governor is to operate are known. If these factors are not known, the motor manufacturer can only suggest a rather large value of resistance in order to prevent runaway speeds at light loads. This may not permit the appliance manufacturer to secure the torque range desired on high speeds nor to secure the range of speeds needed. Similarly, the motor manufacturer must determine from the data submitted to him just which type of motor winding will serve best to cover the speed and torque range specified and permit minimum current through contact points.

D.C. Polarity Effect

It follows from the above discussion that a motor designed to operate over a speed range of 2,000 to 8,000 r.p.m. requires a much more powerful initial winding than one that is to operate over a range of 2,000 to 4,000 r.p.m. and will therefore be larger than motors operating over a narrow speed range, unless the torque requirements are very light.

While governor-controlled motors can be used on both alternating and direct current, they should, if used on direct current, be arranged so that polarity may be occasionally reversed. In this way electrolytic action on the contact points, which causes migration of material from one contact point to the other, can be avoided. Such migration builds up small humps on one of the contacts, and causes corresponding depressions on the other. Another difficulty caused by polarity effect is the difference in wear on the commutator brushes, the negative brush wearing considerably faster than the positive one.

Polarity reversal can be easily accomplished for the permanently installed motor by use of a suitable reversing on-and-off switch. If the device is portable, being plugged in from time to time, the laws of chance will insure sufficient reversals.

Besides their many advantages, governor controlled motors have their disadvantages and limitations. The principal ones are as follows:

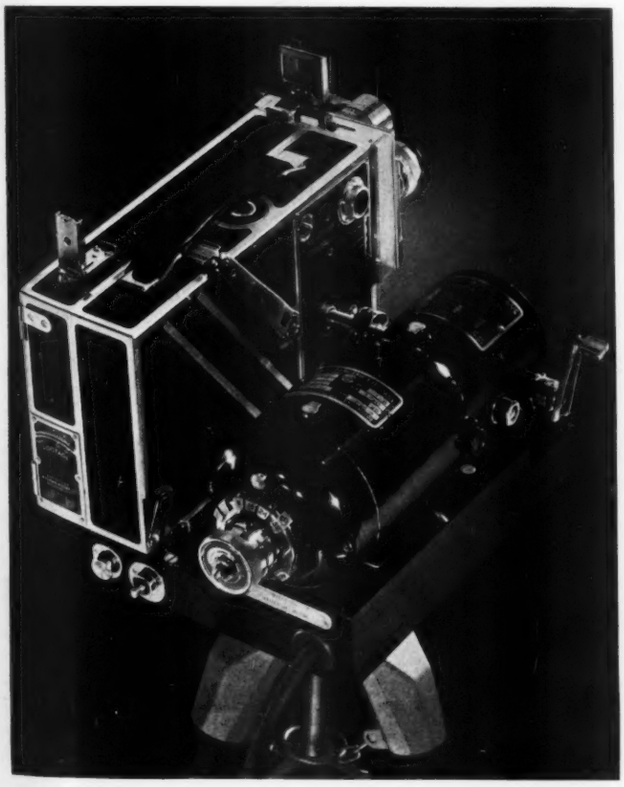
1. Speed Limits. Best operation of governor-controlled motors is in the speed range between 2,000 r.p.m. and 8,000 r.p.m. Operation at higher or lower speeds is seldom satisfactory. Slip ring friction and windage increase with speed, the losses becoming excessive at speeds higher than 8,000 r.p.m. At speeds below 2,000 r.p.m. the motor tends to operate in a somewhat jerky fashion. The most sensitive governor action is obtained when the range between maximum and minimum speed is the smallest.

2—Less Quiet. Governor-controlled universal motors are inherently more noisy than motors without governors, if for no other reason than that they contain more moving parts. Vibration of the governor contacts in following speed changes is sufficient to cause an audible sound which seems directly related to the moment of inertia of the vibrating outer contact member. Also, most governor motors have more brushes and the armature of the governor motor is subjected to vibrating forces developed by the sudden changes in flux density that follow the actions of the governor.

3—More Maintenance. Brushes and contact points require attention, particularly on continuously running motors. Because these conditions are worse on direct current, universal motors are seldom recommended for constant duty d.c. operation.

4—Higher First Cost. Governor motors may be 200 percent higher in price than ordinary series motors, the price difference varying with quantity.

5.—Speed Irregularities. Manufacturing tolerances, temperature variations, and the necessity for clearance on moving parts cause some irregularities in speed control. These are inconsequential for most applications. On devices requiring a high degree of accuracy in speed, they can be minimized by careful engineering and manufacture. If the motor is of the sleeve bearing type with a governor adjustable while running, motor armature and play may cause slight changes in the governed speed caused by the governor which is mounted upon the shaft moving nearer and farther from the end of the control plunger. This end play can be overcome through the use of ball bearings, one of which is suitably locked, or through careful adjustment of the motor spacing washers to provide minimum end play.



Motion picture cameras are driven by universal motors with speed governor adjustable while motor is running by turning knob to calibrated stops. To the rear of the motor can be seen the reduction unit

Engineering Co-operation

That these disadvantages have not been sufficiently great to seriously hinder the application of governor-controlled motors is evident from the ever increasing thousands of such motors being produced. Designers realize that, despite their limitations, governor-controlled motors offer certain performance characteristics which are unobtainable from any other motor of like size.

It must, however, be clear that governor-controlled motors should not be simply ordered from the stock shelf. One cannot purchase a motor of three times the required output "just in case" and hope to secure the excellent performance of a motor designed for the job. There is no type of fractional horsepower motor which requires, in its application, as much careful engineering co-operation between motor manufacturer and user as does the governor-controlled motor.

DROP FORGINGS

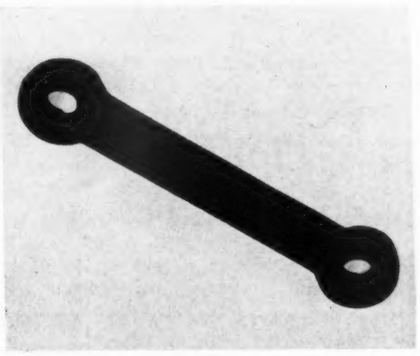
Design Fundamentals and Factors Affecting Costs

L. E. SCRANNAGE
Superintendent, Cleveland Hardware & Forging Company

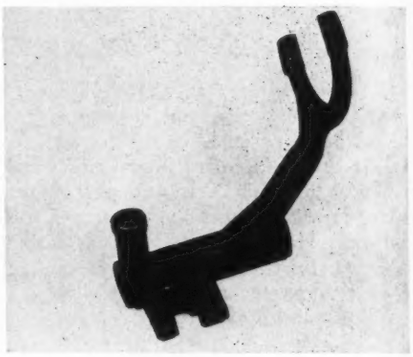
IN THE design of any machine part, after the direction, intensity and character of the loads that will come upon it have been determined, the best shape for the part can then be developed. The best shape will be one wherein every cubic inch of metal contributes its maximum to the strength and rigidity of the part. Frequently, this optimum shape contains losses, double curvatures and unsymmetrical surfaces, making it impossible to produce the part commercially except by forming it to a die, as in drop forging. This process has the further distinct advantages that alloys of high strength can be used, the metal is worked to a denser fiber structure, and, because forgings can be made to close tolerances, machining costs are reduced to a minimum or even eliminated. Thus do forgings contribute to a finished design of maximum strength and rigidity with minimum weight, size and cost.

In designing what are generally termed as "forged parts" it should be remembered that in addition to hammer forging and drop forging, the forging process also includes rolling, upsetting, bending, extruding and pressing operations. Any of these operations or any combination of them are used in the manufacture of economical forgings.

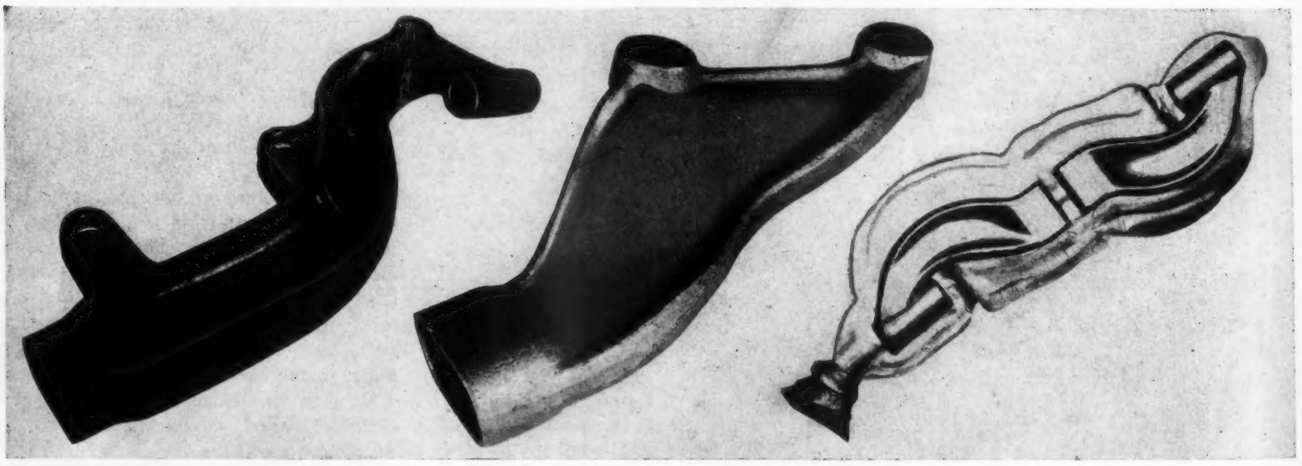
In the following illustrated examples are given some of the fundamental factors to be considered in the design of drop forgings. These include design considerations for most economical productions, for the avoidance of defects and for attaining maximum strength, minimum weight and least total cost.



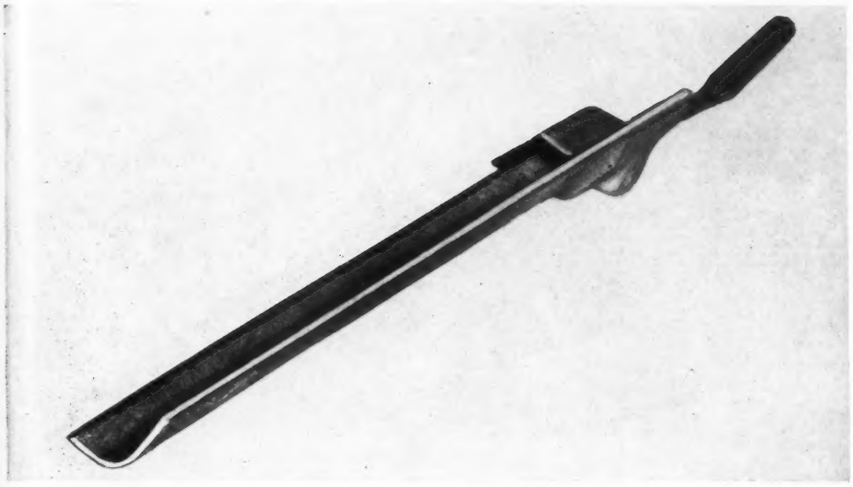
Lowest cost forgings are produced when the plane or planes of the trim or parting lines are such that an equal volume of metal is displaced into the upper and lower die cavities, as illustrated by this forged link. The forging and die costs will both be minimum.



Complicated shapes can be designed so that they can be forged economically by having more than one plane of trim. In the shifter fork shown here, the trim line bends at a right angle. Two steps or passes using two different sets of dies are required to make the part.



Two pieces instead of one are sometimes more economical to make, as in the example shown here. Made in one piece, the forging weighed 7 lb.; made in two pieces, one weighed 2.4 lb., the other 1.4 lb., a total of 3.8 lb., thereby saving 3.2 lb. Other savings by designing the part as two pieces: (1) The one-piece forging required milling the faces of the lugs; the redesign substituted coining to size. (2) The two-piece redesign was more favorable to heat-treatment without distortion, gradually changing from thin to heavy sections by providing ample fillets at intersections of surfaces. (3) The combination of forging and upsetting the ends tends to increase the strength at the cupped end which has approximately 1/8 in. wall thickness. (4) The total costs of one-piece forgings and the two-piece redesign are about in proportion to the weights, namely, the total costs were reduced about 45 per cent.



Thin sections, although they offer great resistance to flow of metal, can be forged but may offer some difficulties. These stainless steel turbine blades are a good example. Flat unribbed sections have a tendency to warp while cooling and if thin sections are heat-treated, the difficulties encountered will vary about directly with the abruptness in changes of metal cross-section.

FOUR MAIN STEPS IN MAKING DROP FORGINGS

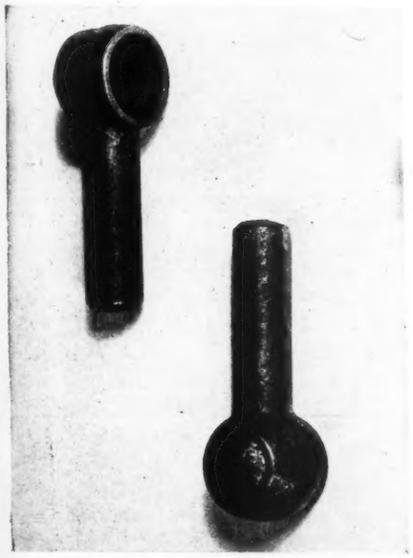
1. The edger—Bends, squeezes, reduces or otherwise roughly shapes the bar to the general outline for the next operation.

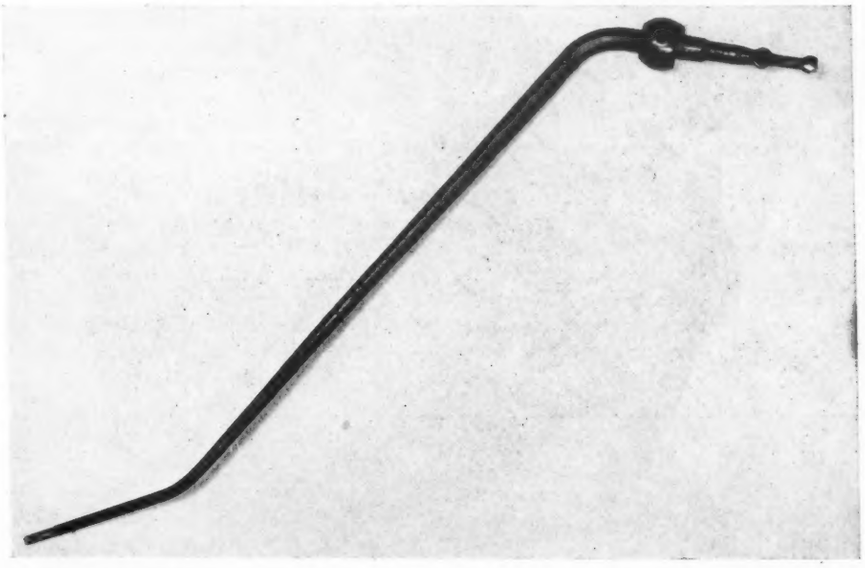
2. Blocking—Brings the bar to the approximate shape and size of the part for the finishing operation.

3. Finish Forgings—Forms the piece to its final shape.

4. Cut-off—Forging is cut from the bar.

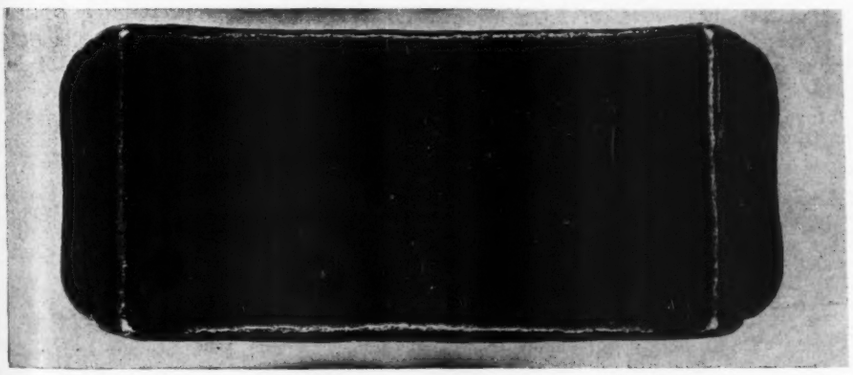
Subsequent operations may include trimming, straightening, coining, and similar operations.





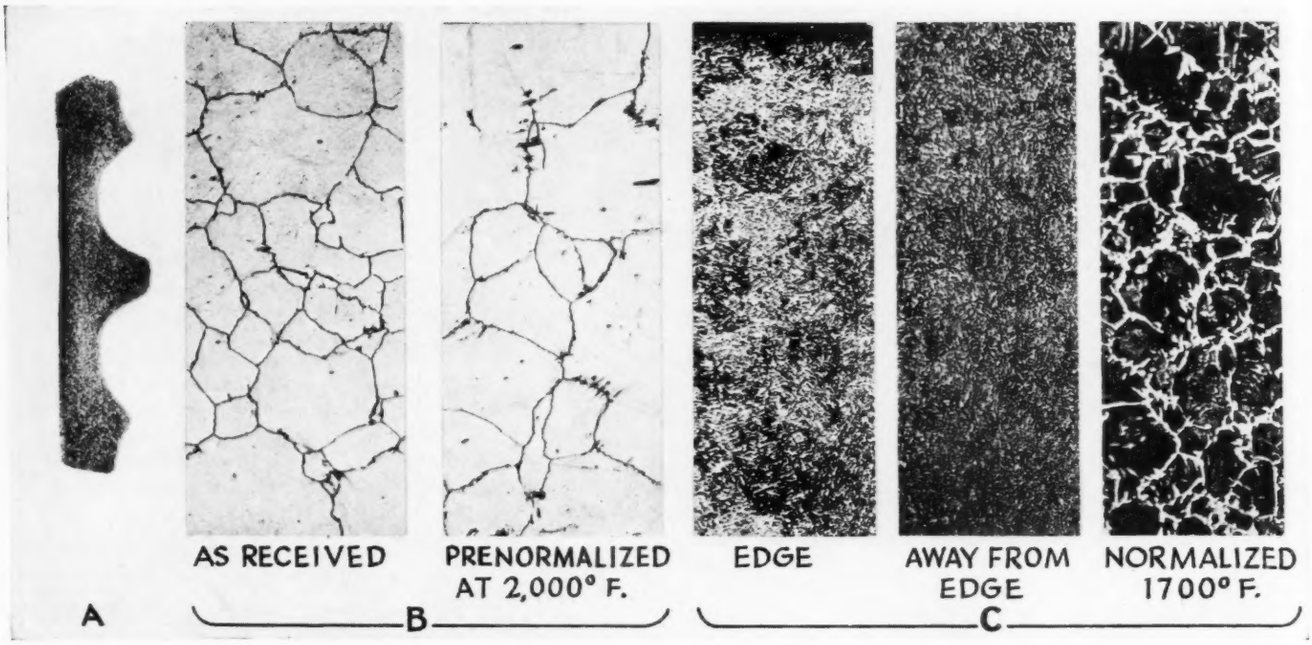
Thin-walled cupped sections chill rapidly when in contact with the metal of the die giving the forging a tendency to stick or freeze to the die. A 7 deg. draft for outside surface and 10 deg. or more for inside is recommended.

Machining operations on the forging may greatly affect its design. Thus, in this gear shift lever, the section from the larger ball to the lower end must be forged concentrically and in alignment to allow for milling, coining and centerless grinding of the working faces. This example demonstrates why the designer must fully specify all subsequent operations to be put on the part, the location of gaging points, and the use to which the part is to be put.



Quench cracks may result from a number of causes. Coarse grained steel is one of them. In the quench crack failure at the left the steel analyzed 0.38 C., 0.78 Mn., 0.017 P., 0.028S and 0.11 Si. McQuaid Ehn test showed grain sizes 1 to 4 after forging and when normalized at 2,000 deg. F., grain sizes 1 to 3, with many larger than 1. Hardness was 23 to 25 Rockwell C and depth of decarburization was negligible. Finer grained steel having greater ductility would withstand the quenching stresses better.

(Continued on Next Page)



Fine grained steels minimize forging and heat-treating difficulties in that they have a wider range of heat-treating temperature and are less susceptible to cracking during forging and heat-treating. Although some authorities do not agree, finer grain steels seem to eliminate the forging defect of worm holes. The micrographs, 100X, show: *A* the result of an etched hot (50 per cent hydro-chloric acid) test for worm holes; *B* the sodium picrate McQuaid-Ehn test, and *C* the 4 per cent Nital micrographs of the original forging before and after normalizing. From such evidence it is concluded that the coarser grained steels often result in failures of this type in heat-treated forgings.

From the standpoint of the drop forger it appears that the finer grain steels require less hammer blows possibly prolonging die life, fewer unfilled forgings, and a lessening tendency toward overstrain and rupture in cases of extreme deformation. Although there is discussion to the contrary finer grain steels seem to eliminate the forging defects known as "worm holes." There is little doubt that the finer grain steels eliminate the "trimmer cracks" developing in heat treating as the result of minute ruptures at the flash line.

Mechanical failures are traceable to laps, seams, cold shuts in the rolling and forging processes, or to the abrupt sharp step changes in section from thin to thick portions and the presence of sharp edges and corners at intersecting surfaces. Cracks may also develop due to hardness variation in the sections resulting from the varying degrees of contraction and expansion.

TEN STEPS IN DESIGNING FORGINGS

1. Having developed the approximate shape, study the possible locations of the parting line. If it can be parted in one horizontal plane, die costs will be a minimum.

2. Develop the shape so that the volumes about the centerline of the forging will be balanced to minimize the tendency of side and end shifts during the forging operations. If volumes cannot be balanced, frequent hammer adjustments will be necessary and rejected forgings high, both of which increase costs. Locked dies must be used.

3. Abrupt step changes in sections and volumes should be eliminated. Eliminate all sharp edges and intersections by providing generous fillets. This offers least resistance to plastic flow.

4. Draft above and below parting line should be 7 deg. or more to give longest die life and minimum die maintenance costs. Draft increases as dies wear.

5. All dimensions in the direction across the parting line should be indicated from the parting line to the deepest points in the die, and not overall unless they are to be held to certain tolerances which should then be specified.

6. Avoid changes in shape or section that might cause variations in flash and thereby produce a tendency to warp the forging in hot trimming or cause splitting of the fibers when cold trimming. Such changes in section can be eliminated by adding metal on top or bottom. This may also have the added advantages of avoiding expensive additional forging operations and making unnecessary extra tolerances to compensate for varying temperatures in the non-uniform section; especially when subsequent bending operations are required.

7. Doubling the tolerances generally more than doubles the die life. Allow the maximum tolerances, balancing the cost of reworking the dies against the cost of subsequent operations to bring the dimensions within the allowable limits. Tolerances should be specified only for controlling dimensions, leaving the others as variables in the forging process.

8. Designate the manner of holding the part in subsequent machining operations and the gage points from which finished dimensions are to be measured, making allowances for the growth of the forging.

9. Specify chemical analysis of the material, grain size, heat-treatment, hardness, required straightness, machinability and the physical properties of the material.

10. Study each factor with the object of attaining maximum strength and stiffness and minimum weight and cost for the finished forging.

METALLIC COATINGS

for Protection and Appearance

J. DELMONTE

Six methods for applying metallic coatings with a discussion of the relative merits and limitations of the various metals applied by these processes

THERE ARE numerous methods employed in the application of metallic coatings. Some of them are adaptable to specific types while others serve a greater variety of metals. Electroplating is regarded as the most general method of applying one metal upon another. The flexibility of its operation is an asset to numerous metal products. For the more expensive metals, there is decided economy in electroplating, inasmuch as the metallic salts derived from the ores may be used in an electrolytic bath, and all of the metal plated on the final surface.

Electroplating small machine parts such as die-castings, screw machine parts or sub-assemblies, may be accomplished by barrel-plating, the parts being tumbled over one another while the electrolyte is kept in constant agitation. The cost advantages of barrel-plating are realized when the labor to place small parts on individual racks for plating baths becomes excessive.

Semi-automatic electroplating is an efficient finishing method for medium to large size metal parts. In a system of this description, endless conveyors making contact with the cathode side of the low voltage power supply, draw parts being plated through the plating solution at such a rate that the time required for plating is equal to the time consumed in traversing the bath. In a like manner the parts may be conveyed to cleaning and rinsing baths.

In all electroplating a good chemical control of the bath is essential, if uniform and satisfactory metal coatings are to be realized. The pH content must be checked frequently, the salts replenished, and the anodes renewed as needed.

HOT DIPPING — Another common method of applying metal coatings is by hot-dipping. This method is practically confined to metals and alloys of low melting point such as zinc, tin, or tin-lead solder. As the name implies, the parts to be coated are dipped into a molten bath of the plating metal. Heavy coats are readily obtainable, contingent of course upon the bath temperature, size of part and the total time of immersion. While control over the coating thickness is not obtained to the same degree of precision as in electroplating, hot-dipped surfaces are fairly uniform.

METAL SPRAYING—The metal spraying technique, developed by Dr. Schoop in 1909, offers certain advantages. Before spraying, the surface is roughened by sand-blasting. Thick coats are easily obtained on large surfaces, or portions of large surfaces such as the inside of large boilers, and the part sprayed receives the benefit of the protective value of the applied metal. Most metals can be sprayed in molten form, including low and high carbon steel, phosphor bronze, zinc, tin and aluminum.

In certain applications, corroded and worn parts can be rendered fit for service with a fresh, protective metal layer by the spraying method. The metal is fed to the spray gun in wire form, being melted by an oxy-acetylene flame as it passes through the gun and issues from the gun in a fine spray of molten particles, propelled by an air jet at high velocity. The particles flatten themselves by impact on the surface and form an over-lapping structure. Other ramifications of this method have been developed, whereby the metal is preheated and melted in a crucible, before being fed to the spray gun.

Coatings obtained from the spraying of molten metals can be any thickness greater than 0.001 in. The metal spraying process is not limited to metal objects, for surfaces such as those of plaster of paris are similarly coated. Likewise, prior to the introduction of the all-metal vacuum tube, one manufacturer found it expedient to spray the glass envelope of his tubes with a zinc alloy, to obtain the benefits of radio shielding.

Mass production cleaning subsequent to copper and nickel plating, preparatory to the final chrome plate

BRUSH PLATING AND VACUUM PLATING —Two comparatively new methods of plating one metal with another, are brush plating and vacuum plating. In

brush plating, the anode is positioned among the brush bristles which are dipped in a moist, pasty mixture of the electrolytic salts to be applied. The brush is moved, as in painting, over the metallic object, which serves as the cathode. The method is of advantage to jobbers, who may touch up electroplating jobs that have slight imperfections. Of course, the wastage of materials precludes brush plating on a wide scale in manufacturing.

Vacuum plating is conducted within a semi-spherical inclosure, with all the necessary metal parts and ingredients. No electrolytic bath is required. The plating metal, in vaporizing, settles upon the surface of the object, depositing a highly reflective film. Close control over the deposit is claimed.

Miscellaneous Methods—Mechanical rolling and cementation are other processes for placing protective metallic coats on metal surfaces. The former is necessarily limited to flat sheet stock as the desired metal is hot-rolled upon the underplate at elevated temperatures. A few outstanding examples of this method of application include nickel-plated and monel-plated steel for chemical process apparatus; tantalum-plated tungsten for high temperatures in transmitting tubes; and tinned steel cans.

Cementation involves the formation of an alloy of the base metal and coating metal. Tungsten and molybdenum have recently been applied experimentally to steel in this manner.

Sputtering under vacuum and the silvering of glass surfaces, are methods employed in the manufacture of highly reflective glass mirrors. Other processes for coating metals are employed by vacuum tube manufacturers, where monoatomic layers of metal are applied upon sensitized surfaces during the evacuation of the tubes.

From this very brief review of the common methods of applying metallic coatings, one can visualize the magnitude of the field of industrial finishings by the more common metals. A discussion of the relative merits, limitations, and qualities of the various metals that can be applied by these processes follows:

Zinc—A metallic coating is usually not regarded as completely isolating the base metal from the corrosive medium, on account of tiny "pin-holes" or possible slight breaks in the film. But a zinc coating protects the ferrous metal by sacrificing itself. In other words, under the conditions of exposure that tend to corrode the metal, the zinc, by reason of its greater activity, will be affected instead of the iron. That is why the protective qualities of zinc are directly proportional to the thickness of the coating. Heavier coatings of zinc are preferred for articles exposed to outdoor weather and marine atmospheres.

Zinc is applied to ferrous metals by several methods such as electroplating, hot-dipping, metal spray, and sheradizing. Recent investigations by the Bureau of Standards indicate that electroplated zinc coatings have the same protective value as hot-dipped coatings of the same thickness.

Two standard baths are available for electroplating zinc: zinc cyanide bath and zinc acid sulphate bath. The cyanide bath is to be preferred for articles with numerous recesses because it has superior throwing power. That is, the cyanide bath has a greater capacity for depositing metal furthest from the anode. Zinc acid sulphate baths are preferred for depositing heavy coats upon wire, at high current densities. For iron wire, the deposits range up to 0.005 in. though such thicknesses are seldom applied because the possibilities of cracking are increased. Thin coatings of 0.001 in. to 0.005 in. are usually applied for coatings to be exposed to industrial atmospheres. They offer superior and more lasting protective qualities than cadmium, nickel, and chromium in these atmospheres. In uncontaminated rural atmospheres, 0.0005 in. of zinc and cadmium give equal protection.

ZINC COATINGS

Method of Application	Typical Applications
Electroplating (Zinc cyanide)	Conduit tubing, fittings, locks, tire chains, builders' hardware
Electroplating (Zinc acid sulphate)	Wire for outdoor exposure
Hot Dipping	Galvanized steel sheet, pails, structural steel, marine hardware
Sheradizing	Small iron and steel parts, castings
Molten spray	Parts of large assemblies. Large tanks. Suitable for almost any base material

For other than quantity production, the simple plating vat is used

Hot dipping or galvanizing in molten zinc is conducted at temperatures of about 850 deg. F. for structural steel and pipes, and at about 900 deg. F. for wire. In hot dipping, fluxes are recommended for insuring a firm adherence of the coating. Zinc ammonium chloride and sal ammoniac are commonly used.

Where good appearance is not paramount, sheradizing offers certain economies in the application of zinc plating. The parts to be plated together with zinc dust are heated in a slowly rotating container. The zinc sublimes and forms an alloy with the iron, a dark colored protective layer. A large number of parts may be handled in one container. If the part has small recesses from which it is difficult to get rid of the zinc dust, some one of the other methods should be used for plating.

For attractive surface finishing, various expedients are available to render a bright finish on the zinc plating. One of the least expensive ways is to give the zinc plated objects a short dip in mild nitric acid. On the other hand, bright zinc deposits are obtained directly from the plating bath when a small amount of molybdenum is deposited with the zinc. Bright zinc coatings are also obtained commercially from cyanide plating solutions containing ammonium thiocyanate formaldehyde resin or thiourea formaldehyde resin. These resins are soluble in the plating solutions. When a uniform dark finish is desired on zinc, an electrolytic low voltage a.c. treatment in chromic acid will darken the zinc parts.

Zinc coatings have an advantage over other metals in their low cost and comparatively high durability to general atmospheric conditions. Cadmium offers serious competition as a durable protective coating, particularly in the neighborhood of sea water or where salt water spray is present. Cadmium and zinc have withstood atmospheric exposures better than nickel and chromium, in recent tests of the Bureau of Standards. There is another advantage in zinc coatings, not often brought to light. Tests on the corrosion fatigue of steel parts, with various types of protective coatings, reveal the superiority of zinc. This may be attributed, in part, to the fact that zinc absorbs hydrogen less readily than other metals, and hence is not subject to an embrittling action during plating and cleaning. In tests conducted by the author, zinc plated parts had a higher fatigue limit than analogous parts coated with nickel, chromium and cadmium, which had been heat-treated to relieve in part the hydrogen embrittlement. Chromium was the worst offender in this respect.

CADMIUM—Cadmium-plated parts have gained wide popularity in recent years. Small bolts, nuts, screws, rivets, pins, and washers are barrel-plated on a large scale, to resist corrosive influences. Cadmium plating imparts a bright, attractive, silvery-white finish to the surface. The thickness of the coating varies from 0.0002 in. to 0.0015 in., the average article, not less than 0.0003 in. thickness.

As an example of cadmium plating, one of the leading radio manufacturers electroplates 0.0003 in. on radio chassis, in an 8 min. plating cycle. An automatic plating machine completes 1,000 pieces per hr. The cadmium plating not only resists corrosive influences, but it also permits rapid soldering of parts and connections to the radio chassis. Sometimes a slight yellow tint may be apparent upon the cadmium plating. This may result from a rinse in potassium dichromate after the electroplating operation. To avoid finger stains, a clear lacquer coating is usually applied over cadmium plated parts that are to be handled frequently.

For plating cadmium in a tank, the usual voltage is from 4 to 6, while it is 8 to 12 volts for barrel plating. Copper and brass parts should receive a strong acid etch before being plated with cadmium. To brighten the cadmium deposit, flake hide glue or molasses should be added to the bath. For a very white, matte type of finish, 0.08 to 0.16 per cent gelatin should be added to the plating solution. On completion of the plating operation, the parts should be rinsed in clean, cold water, and then immersed in a 5 per cent solution of chromic acid. The chromic acid passivates the cadmium surface and greatly improves the adhesion of paint or lacquer films to the cadmium plate.

Cadmium is the equivalent of zinc in general atmospheric protection, and is superior to it in sea water exposure. It protects ferrous metals by sacrificing itself, in much the same manner as zinc. Like zinc, however, it is soft, and does not possess high wear resistance.

TIN—As a protective coating, tin is widely used in certain food receptacles and household applications. Until recently, tin coatings were applied almost universally by dipping and mechanical rolling, but newly developed electro-tinning operations have attracted some of the trade. One of the earliest applications of tinning, as a protective finish, was to stranded copper wires, which were to be used in rubber covered conductors. Copper is attacked by the sulphur in the rubber while tin is resistant. Tin is likewise resistant to most organic acids, making it a desirable plating for tinned cans, milk pails, food containers. In the manufacture of tin cans, the sheets are hot-dipped or rolled with tin. After fabrication, with the tin-plate in place, they are heated above the melting point of the tin, which flows and fills all pin holes and cracks. The superposition of an electro-tinning operation upon a hot-dipping operation has been known to improve the quality of the tinplate and reduce the number of pin holes.

Tin has been applied by spraying to various containers handling organic ingredients. However, when the articles are irregular in shape, with many recesses, electro-tinning should be used. Besides, there is less wastage of material in electroplating, as compared to hot-dipping. Typical applications of electro-tinning include: water tanks, copper refrigerator coils, brass builders' hardware and washing machine parts. Though tin tarnishes slowly, it scratches easily and may lead to early corrosion at the points where the protective layers have been broken. In the deposition of tin, the chief disadvantage lies in pin holes and porous spots.

LEAD—The chief field of application of lead as a protective coating lies in equipment requiring resistance to chemical attack or salt water. Marine water boxes and large copper pipes for salt water have been sprayed with lead, and a decided improvement noted in the life of such equipment. The extreme softness of lead, its dull appearance and heavy weight, make its use limited in product design, where its corrosion resisting properties might otherwise be of advantage.

COPPER—Copper, as a protective coating, though not as widely applied as other metals, does serve as an excellent intermediary for a nickel or silver plating. The exposure of copper to the atmosphere results in a bluish-green tarnish, which sometimes enhances the appearance of exterior decorations on buildings. To preserve the reddish appearance of the copper for decorative purposes, a clear lacquer or varnish may be applied. A plating of cadmium or nickel may be necessary on copper, brass or phosphor bronze parts that are to be used in contact with iron or aluminum. Otherwise, the corrosion resulting from the contact of dissimilar metals would be excessive, leading to early deterioration of the assembly.

Copper alloys, brass, bronze and phosphor bronze are sometimes sprayed on worn or eroded machine parts of the same metal. The spraying of bronze on statuettes lends an attractive appearance to the finished article. There have also been noteworthy results in the plating of brass and bronze. Brass platings are of value to miscellaneous interior hardware and hollow-ware of german silver. The use of copper cyanide and sodium stannate, with cast bronze anodes, has given good results in bronze plating. A durable, hard deposit of bronze may be attained comparable to hard nickel deposits of equal thickness.

(To be continued)

TYPICAL VARIABLE-SPEED TR

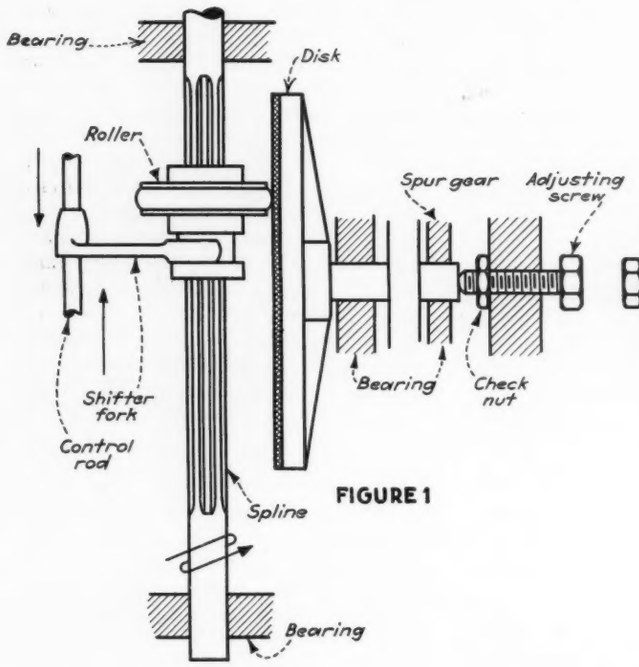


FIGURE 1

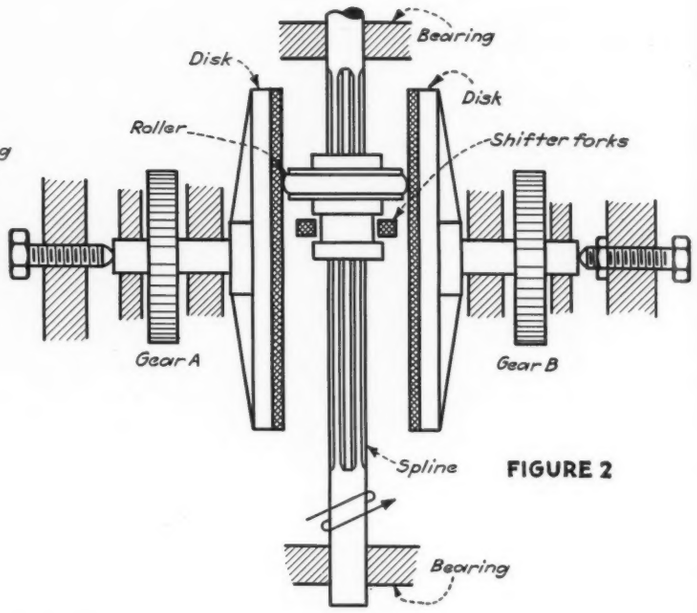


FIGURE 2

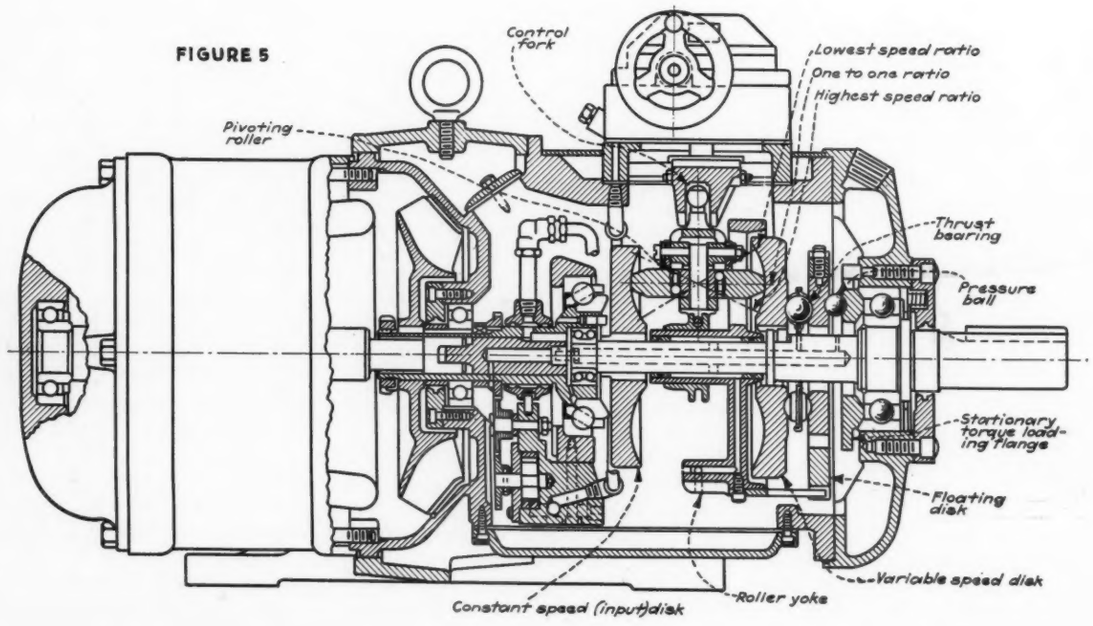
FIG. 1—Motion transmitted between roller and disk with speed ratio changed by sliding roller along splined shaft. Either roller or disk may be driver and either shaft may rotate at uniform speed. Practical for light drives only, since pressure of adjusting screw tends to cause excessive friction at bearings when large torques are transmitted. Moving roller across center line of disk reverses motion. A coiled spring may be used instead of the adjusting screw.

FIG. 2—Similar to Fig. 1, but friction on bearings reduced by adding a second disk and adjusting screw; thus relieving the splined shaft bearings of excessive pressure and increasing the mechanical efficiency of the unit. Gear *A* and Gear *B* turn in opposite directions and either may be the driver.

FIG. 3—A balanced double disk drive with the thrust balanced as in Fig. 2, but with the rollers pivoted on their axis as a means of varying the speed ratio. With the rollers in a horizontal position both shafts rotate at the same speed, but as the rollers are pivoted the driving radii of one disk increases as the other decreases, thus varying the speed ratio.

FIG. 4—Similar to Fig. 1, this Lenney variable speed transmission employs an automatic device for increasing the pressure between the roller and disk whenever the torque is increased. There are two driving disks, the first is fastened solidly to the driving shaft and transmits motion to the second disk which is free to float around and along the shaft. The force of the second disk is in contact with the roller and

FIGURE 5



DTRANSMISSIONS—I

CYRIL DONALDSON
Rochester Athenaeum & Mechanics Institute

Mechanisms and devices for variable-speed driving of heavy or light loads and covering various ranges of speed ratio, some of them for reversing rotation

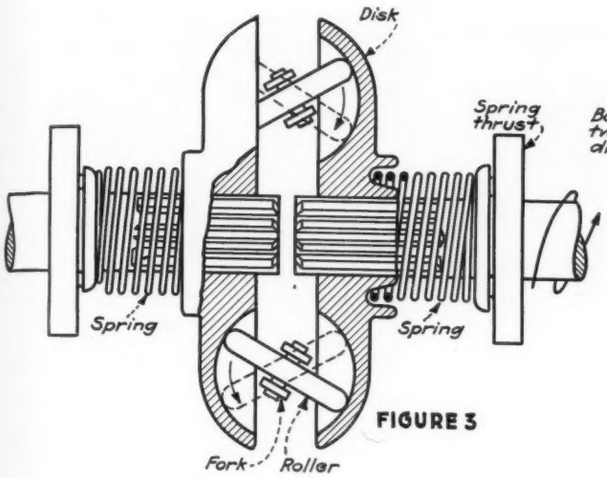


FIGURE 3

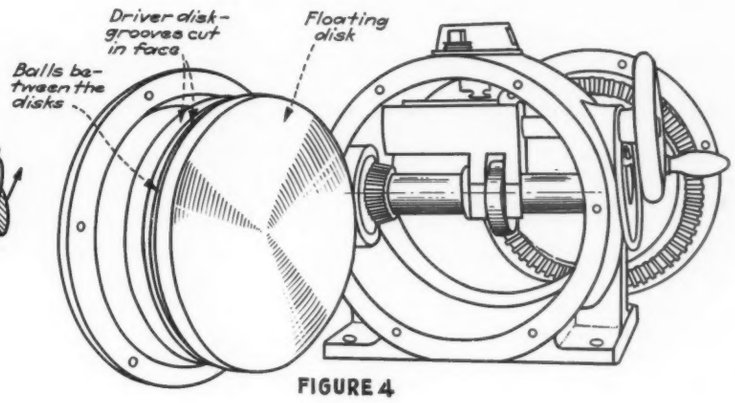


FIGURE 4

variation of the driven shaft speed is effected by moving the roller across this face. The hand adjusting screw of Fig. 1 is replaced by the loading device which operates as follows: the driver disk has four V-shaped grooves of the same radii cut concentrically in its face, each groove forming an arc of about 80 deg. varying uniformly in depth from a maximum at one end to a minimum at the other. Into each of these grooves is fitted a ball held in position by a suitable spacer. These balls press lightly against the floating disk when the unit is stationary, but the torque resistance from the driven roller causes the floating disk to lag behind the driver disk, thus forcing the balls to roll up the ramp formed in the grooves and press harder and harder against the driving disk, thus exerting a pressure between the driving surfaces proportional to the torque transmitted.

FIG. 5—Similar to Fig. 3, this New Departure Transitorq has three rollers and makes extensive use of ball bearings both for radial and thrust loads. Pressure between rollers and disk automatically increase with torque by means of the ball and tapered groove method. Three balls, held in place by a suitable spider, roll up the ramp when the floating disk rotates with respect to the output race. This causes a definite axial movement of the floating disk, thus increasing the pressure between the driving surfaces in proportion to load.

FIG. 6—Modification of disk and roller type to provide automatic reverse, as in tapping machines. Surface of disk curved to form circular arc with center at pivot point of motor. Contact surfaces of rollers curved to match surface of disk. Rollers fastened solidly to driven shaft. Shaft has sufficient endplay (exclusive of tapping movement) so that downward pressure causes contact with upper roller only. When withdrawing tap, the pressure is reversed and lower roller engages disk causing reversal at higher speed.

FIG. 7—An attempt to avoid undue wear by providing point contact rather than line contact, this Thompson transmission employs a disk, sphere and cylinder. The speed ratio is altered by moving the sphere along the cylinder.

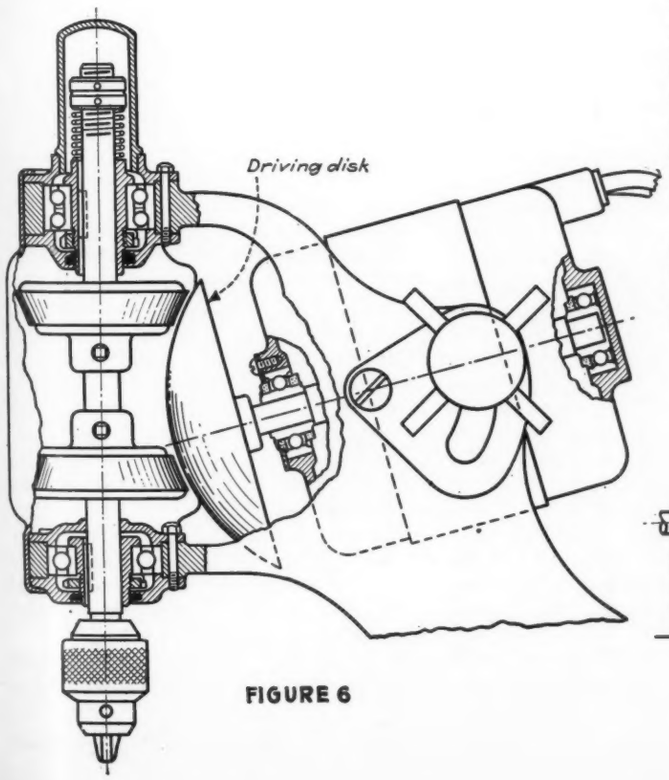


FIGURE 6

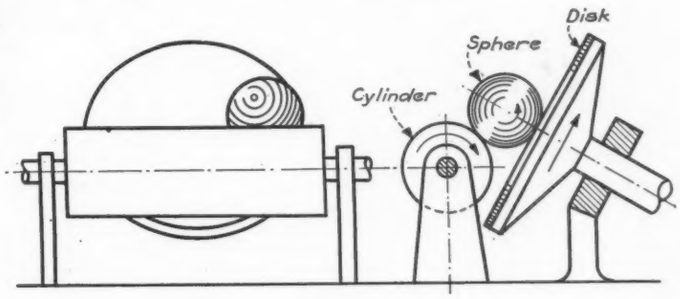


FIGURE 7

Question and Comment

Viewpoints on the Patent Question

Research directors and company officials in discussing the editorial "Can There Be Progress Without Profit?" point out numerous other harmful results should any attempt be made to suppress patent rights

Many patent attorneys, company officials and engineers sent us discussions and comments about the editorial "Can There Be Progress Without Profit?" which appeared in our February number. Unfortunately, space will not permit us to publish all of the comments in full.

One of the most comprehensive discussions received was that from R. W. King, assistant to President F. B. Jewett of the Bell Telephone Laboratories. The following are abstracts quoted from Mr. King's letter:

"In connection with the general question of suppression of patents, I wonder if you are familiar with the so-called Oldfield Bill which was before Congress some 25 years ago and, more particularly, with the thorough-going discussion of the majority and minority reports thereon which was published in 1913 by the Harvard Law Review Association under the title of "The Proposed Patent Law Revision—What It Means to Inventors, Manufacturers, Dealers, and the Public" by Gilbert H. Montague? You will see from these reports that the thought that patents are suppressed is neither original nor well-founded.

"The Oldfield Bill was based upon the belief, which later developed to be entirely emotional in its origin, that important patents were being suppressed and that the public was the loser thereby. The Bill ultimately failed of enactment and the minority report of the Committee which held hearings relative to it stated as follows: 'If the practice of buying up patents for the purpose of extinction is as prevalent and as harmful as the majority contends, it is somewhat extraordinary that the majority has been unable to show a single case of the purchase of a patent for such a purpose, and only a single case in which a patent of any value was, in fact, suppressed for the purpose of preventing competition with another product manufactured by the owner of the patent.'

"In regard to the 'single case' referred to in this quotation, it should be mentioned further that the Supreme Court, in ruling upon it, decided that the rights of the public were not involved and that there was not suppression. It was disclosed that the situation involved the rejection of one invention and the use of a better invention accomplishing the same purpose more satisfactorily. The broad fact, therefore, is that the charge of suppression failed absolutely of proof.

"It is also worth recalling that Thomas A. Edison, when testifying before the Committee, said: 'I have heard and read numerous statements that many corporations buy valuable inventions, but no one cites specific cases. I myself do not know of a single case.'

"The thought will naturally occur that this evidence is old and that conditions may have grown appreciably worse. I think, however, that one can readily assure himself on this point by recalling that as industries develop and become more complex—a trend which has characterized particularly the last 25 years—the possibility of obtaining basic and very controlling patents becomes smaller and smaller, and at the present time in most industrial lines is almost nonexistent. The only reasonable supposition, therefore, is that patent monopolies are not and never have been used to withhold valuable developments from public use.

"It might be pointed out, just by way of confirmation, that the experience of foreign countries where compulsory licensing laws obtain, fully bears out this statement. Requests for licenses under 'unused' patents are so rare as to be insignificant. In England from 1911 to 1934 there were only eleven all told, most of these related to the patents of foreigners who had failed to introduce the invention into the Kingdom in any form.

"Returning to your editorial, I should like to compliment you particularly upon your statement relative to the cost of valuable patents, there necessarily being a good many useless inventions to every really important one. As you point out, millions are spent on research, much of which is—let us not say 'fruitless'—but necessary for purposes of exploration. And this is a fact which may readily be overlooked by zealous legislators bent on curing an imaginary ailment. Their remedy, for instance, might conceivably take the form of a thorough-going law to enforce compulsory licensing. In such a situation, the cards would almost certainly prove to be stacked against the man who had underwritten the research program and who owns the patents. For the would-be licensees are not interested in purchasing licenses under his useless patents—they only want rights under some particularly timely patent, and I fear they might not prove too open-minded when asked for a license fee which, although representing no more than their fair share of the cost of the research work out of which the entire group of patents has arisen, might seem large in terms of a single patent."

New Products Make Employment

R. S. Perry of the Ingersoll Milling Machine Company discusses another angle of this whole situation. We must confess that this point was overlooked in our editorial.

"I have been impressed a number of times in talking to men who are not technically trained that they think of an invention as being a 'hot flash' procedure or the result of some divine inspiration.

"I think it might be well if you stressed this point and pointed out that the real inventive progress in any industry today is the result of a very seriously planned effort. The mechanism which accompanies almost every large company today for new invention and research is a most imposing affair and involves a tremendous outlay of money, high salaries, laboratory equipment, and supervisory talent of the very highest order.

"The only excuse or justification for such an expenditure in any large organization is that the organization may maintain its 'youth' and be perpetual as a creator of new and better products and as a means of employment for those who depend upon it for a living. If it were not for this motive, the people owning the business could run out their

life's span with their present product and the company would die at the end of this period. Our records are full of such business life cycles. The patent law offers protection to those who are building a long run business. I disagree with you that it is an incentive for profit. It is more truly an incentive for the perpetuity of a business rather than for immediate gain or excessive earnings. I think this is a deeper aspect of the patent question than the one which has been raised in your editorial.

"I disagree with your opinion in the fourth paragraph of your editorial that the selling price of a patented article is solely a matter of opinion. This is what is causing trouble. If we look upon the selling price as being based upon legitimate cost of a legitimate long run business, the price will be that at which that business may carry a competent development and research group."

Why Patents Are Withheld

Albert Palmer of the Crompton & Knowles Loom Works comments:

"As you say, those who are not engaged in research and development work probably do not realize the vital importance of the protection which the patent laws afford to industry.

"The statement that corporations use the patent laws to withhold from the public the advantages of the progress of science obviously is based on a misunderstanding of the situation. It is possible that some companies may withhold patents for a number of very good reasons. In the first place, the patents may cover a product or process which accomplishes the same purpose as an existing product or process which is, in every way, satisfactory. If there is no particular economic advantage in the new product or process, why should a company go to the expense of the new development merely to duplicate something which already is in existence?

"I can imagine readily that some corporation might withhold action on a patented article because of the tremendous expense of reducing it to commercial practice. Perhaps the company cannot finance the undertaking and does not want to go to somebody else for financial assistance which may result in the company's losing control of the manufacture and sale of the product or the process.

"Again, the patent may cover a mechanism which in itself is not immediately usable but which, at a later date, may form a part of a complete machine that will perform a useful purpose. There are many instances of this sort of patent—improvements which, by themselves, are not usable, yet which eventually may constitute a very valuable element of some machinery in which they are combined with other mechanisms.

"I have an idea that some inventions are held back because certain sections of the public would be affected adversely while the remainder benefited greatly. I heard of a case where some men had been working for a number of years on a machine which would make a fundamental change in a business with which everybody is familiar. The general public would benefit through the improved process, but groups of people over the entire country would be thrown out of work. The men who have been working on the machine may be accused of holding back the invention, but I fancy that some of our friends in Washington would thank them for doing so.

"As far as prices are concerned, it is obvious that initially they must be higher than they will be eventually. As you point out, the original development cost is very expensive in most cases and the cost of reducing the idea to commercial practice even greater. A corporation or an individual body must try to estimate his market and charge as a part of the selling price the prorated cost of developing and introducing the product. Experience shows that as time goes on the cost of the development and promotion work is absorbed, the methods of production are improved and the price is reduced. We only have to look about us to see innumerable examples.

"I am of the opinion that the laws of economics and of human nature act to prevent corporations from withholding new products from the public and from maintaining high prices. Possibly for a short time an artificial situation may be maintained for the reasons which are enumerated above. However, in the long run, they will be more effective in correcting these alleged abuses than any discouraging legislation which is proposed for the modification of the patent laws."

Patents Disclose Progress

The director of the research laboratory of a medium-size corporation writes in to state that:

"One of the great incentives for the support of industrial research by companies in industry is that of the opportunity of gaining a monopoly on their developments to compensate them for their own initiative and expense in making such developments. In compensation for this monopoly the public is informed, through the patents issued, of the development. In other words, the granting of a monopoly is in compensation for making the public disclosure in the form of a patent. If the opportunity for monopoly is denied, the probable reaction will be that if industrial research is done for profit, the findings will be operated as a secret process as long as possible. This will be a very marked step backwards so far as public interest is concerned."

High Prices Not Maintained

J. W. Meadowcroft, assistant to the works manager of the Edward G. Budd Manufacturing Company offers a great deal of food for thought in his statement:

"In all my 30 years' connection with the sheet metal industry and particularly in the development of all-metal automobile wheels and bodies and all-metal bus and railway vehicle bodies, although there have been innumerable improvements in the three decades, I have never known of an improvement of any consequence or lasting utilization which while the patents were yet in force did not reduce the cost of using the product to the ultimate consumer. Often the costs were reduced by amounts considerably more than the amount of royalty paid or of profit made by the manufacturer, or both together, and most often according to the consumer a better quality product than could possibly have been had at the higher cost which prevailed before the invention was made. I think the instances where the contrary is true must be rare indeed."

Low Prices for Profit

A number of additional points that were stressed in various letters emphasized the fact that any suppression of the privileges granted by the patent laws would be more harmful to individuals and small corporations than it would be to large corporations, but that in the final analysis the most fundamental interest is that of the country as a whole.

With reference to maintaining high prices on patented products, it should be pointed out that unless the customer regards the price as reasonable he will not buy and, therefore, any attempt to maintain high prices will greatly limit the market for the product. Only by offering the product at a reasonable price can the manufacturer develop a broad market to permit mass production, thereby lowering costs, make a small profit on each unit sold and thus a greater total profit.

It must also be remembered that the patent system not only encourages inventors to make the inventions in the hope of a profit, but it encourages investors to put their money in new manufacturing enterprises, and it makes it economically wise for old enterprises to buy patents or acquire licenses and also to maintain in their employ persons with inventive talent who may lack other qualities, such as the ability to make good commercial engineering designs and the possession of good financial

judgment, which would be necessary for them to succeed in business as individuals.

Fundamentally, therefore, everything which unwisely hampers the large corporation immediately and directly lowers the value of inventive ability because it reduces the market for inventions, and thereby reduces the opportunity of employment for investors with existing corporations. It also reduces the opportunity for an inventor to start a new enterprising based on his invention because it makes it more difficult to obtain financial backing.

Of course, if the patent system were abolished or the advantages of patent ownership were abolished there would inevitably be a tendency to keep discoveries a secret and thus retard the progress of the useful arts. Discoveries of fundamental facts by research workers would no longer be published so readily and information such as is disclosed in patents would no longer be available. Thus inventors would be deprived of a great amount of material that is now available. Inevitably any policy that abolishes the rights and privileges now granted through patents would be more serious for the individual inventor and the small corporation than it would be for the larger corporations at which such legislation might be aimed. But the greatest loser would be the public.

Special Linkages

JOHN E. HYLER
Peoria, Ill.

That it is entirely possible to accelerate a motion entirely within one slideway is apparent in Fig. 1. Powered from *A* with uniform velocity, the composite slide-block *BF* is held together, ordinarily, by extension-spring I. Fitted with the two toggles *DD*, which engage stationary flanges *E* along the slide-way, the toggles are compressed when travelling in the direction *G* and are allowed to assume their natural position progressively when travelling in direction *H*, thus first throwing *F* ahead, and then allowing it to return. Various curves may be incorporated in the guides *E* to suit various conditions.

A composite slide-block, operating entirely in one slide-way, may also be decelerated on the forward stroke, by the adoption of a parallelogram linkage like that shown in Fig. 2. Here the composite slide-block *AD*, operating in slide-way *C*, advances to the right at constant rate from *B* has the two link-pins *FF* extending through the links and engaging grooves *G*. In the position shown, these pins have reached the point in their travel where the grooves begin to diverge, and further travel to

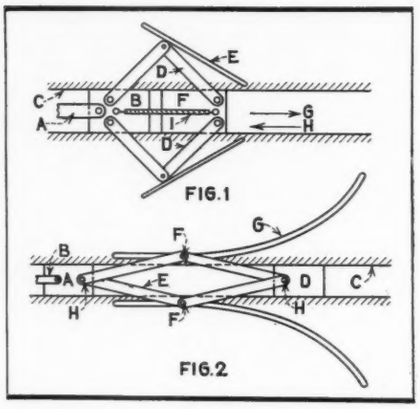


FIG. 1

FIG. 2

the right will pull the corners *FF* of the parallelogram farther apart. This means that *HH* will be drawn closer together. But since *H* on *A* is advancing at constant rate, the entire resultant effect will be the deceleration of *D*, the amount depending on the shape of the curved guides.

How Many Teeth in Contact?

To The Editor:

Recently we had a controversy about the tooth load on a miter gear set employing 24-tooth, 3-diametral-pitch, 2-in. face, 14½ deg. standard-tooth gears. They were to run at 5 r.p.m. and transmit 1 hp. under ordinary conditions of steady drive.

Calculations based on the Lewis formula show that the pitch velocity will be 10.58 ft. per min. and that the load which can be transmitted will be 1,880 lb., which is equal to 0.6 hp. approximately.

The question is whether the tooth load is calculated on a one-tooth contact or a two-tooth contact. If I assume one-tooth contact, only 0.6 hp. can be transmitted, but, if I assume two-tooth contact, then the desired 1 hp. can be transmitted by the set. —J. J. G.
Buffalo, N. Y.

Which Form of Gear Tooth Is More Freely Rolling?

To the Editor:

In connection with a current problem, the writer would appreciate the advice of your readers as to which of the following is the more freely rolling tooth form for bevel gears: the 14½ deg. standard, 20 deg. stub, 20 deg, stub full-depth, 14½ deg. high and low addendum, or 20 deg. high and low addendum.

In addition, I would like to know whether the high and low addendum gears create greater thrust pressure on the pinion bushing than do the standard 14½ deg. and 20 deg. full-depth teeth.
—F. J. J.
Chicago, Ill.

Expose Its Glory

Don't draw lines that smudge or smear
Nor lines so light they stand in fear.
Make them bold and well defined,
A he-man's record of his mind.
Figures place both large and neat,
To strike the eyes of whom they meet.
Strive to balance blacks and greys,
Their beauty wield in divers ways.
Let your picture tell its story,
Of nut or bolt in all its glory.
—HAROLD FOULDS
Cleveland, Ohio

Data on Diamonds

To the Editor:

We will appreciate it if you will furnish us with information concerning the proper selection, application, grinding, lapping and sharpening of diamonds used as cutting tools. We would like to get a list of books published on this subject and we would like to know the names of authorities on this subject.
—M.F.M.
Lancaster, Pa.

Can You Work This One?

H. E. SMITH
Newark, N. J.

Solution to Last Month's Problem—

Telephone Poles

Let X equal the number of poles on each parallel street. Joe had completed putting a cross-arm on three of the poles on the wrong street when Frank arrived, and then finished all but six of the poles on his street. Hence he finished $x-6+3=x-3$ poles. Frank did $x-3+6=x+3$ poles. Therefore, by subtraction, we find that Frank put up six more cross-arms than Joe did.

This Month's Problem—

Two Balls in a Corner

A 12-in diam. ball is placed in a corner of a room. The ball touches both walls and the floor. Find the diameter of a smaller ball that can be placed in the same corner and touching both walls, floor and the surface of the 12-in. ball.

News

Standards Proposed For Surface Finishes

AT THE ANNUAL convention of the American Society of Tool Engineers to be held in Detroit, March 9 to 12, James Weaver, director of equipment of Westinghouse Electric & Manufacturing Company, will lead a discussion on a proposed scale of standards for surface finishes.

In a recent meeting of the Pittsburgh Chapter of the American Society of Tool Engineers, Mr. Weaver proposed a scheme wherein finish grades would be divided into 10 classifications ranging from 0 for the roughest, to No. 9 for the smoothest. The finish 0 would designate a surface finish with an average depth of scratches, tool marks or serrations of 0.063 in., while the No. 9 finish would designate a surface with scratches not more than approximately four one-millionth of an inch in depth. This last is somewhat coarser than a finely lapped surface. Johansson blocks, for instance, have a standard of one-millionth of an inch for depth of surface marks.

According to Mr. Weaver, instruments for measuring surface marks are already available. Dr. G. J. Abbott of the Physicists Research Company has developed one such machine which was demonstrated at one of the annual meetings of the American Society of Mechanical Engineers.

New Fatigue Tester Has Electronic Control

IN THE CONVENTIONAL fatigue bend testing machine, the relation between stroke and load or stress varies as soon as the specimen begins to yield, because for a given set-up the stroke remains constant throughout the test. However, under actual service conditions the load on the member is substantially constant, the amount of bending increasing as the part weakens and yields. In the design of the latest fatigue testing machine developed by Ford engineers, the load applied with each stroke remains constant, the length of stroke varying to compensate for the increased yielding or weakening of the test specimen. Thus, the testing machine more nearly duplicates actual operating conditions.

In this new Ford fatigue testing machine, the load applied at each stroke is measured. The scale or "dynamometer" actuates a mechanism that in turn controls the angular position of a tiny mirror. The mirror flashes a beam of light across a photo-electric cell with each revolution of the machine's flywheel. Thus, as the part being tested begins to fail, the change in angularity of the mirror throws more light on the photocell and thereby increasing the electric current delivered. Through a small relay the current is stepped up and drives a motor that rotates a small worm, the rotation of which increases the length of the stroke.

The machine can be operated at a speed of from 1 to 400 r.p.m. and can be set to deliver strokes to exert loads ranging from 1 to 3,000 lb. at each cycle. The length of strokes can be regulated from 0.002 in. to 4 in. in each direction. A counter registers the exact number of bends or twists that have been applied to the part being tested.

Western Metal Congress Program Completed

WITH EIGHTEEN national technical societies cooperating in the double event, the Western Metal Congress and Exposition to be held in the Pan-Pacific Auditorium and the Biltmore Hotel in Los Angeles, March 21 to 25, promises to excel any similar event ever held on the Pacific Coast. In addition to the many joint meetings sponsored by the American Society for Metals—the American Welding Society, the American Society of Mechanical Engineers, and the Pacific Coast Gas Association will meet independently in their own sessions during the week of the congress and exposition.

Particular attention will be paid by the congress to metals used in the petroleum, aviation, general manufacturing, chemical and mining industries. Eight papers will be presented at the foundries sessions, three on iron and steel, and five on castings and casting processes. Sessions on the machinability of metals will cover the machinability of bessemer screw stock, alloy steels, castings including gray iron and steel, aluminum alloys and other non-ferrous alloys. At a general session, eleven papers will present the latest developments in the metals industry. Three papers will be presented in a symposium on welded oil well casing strings, and three papers in a symposium on large welded pipes for water and power transmission. A total of more than 100 papers will be presented at the congress, in addition to which there will be a series of five educational and informative lectures on the manufacture, treatment and application of iron and steel, presented by Dr. A. Allen Bates, manager of the chemistry and metallurgical department of the Westinghouse Electric & Manufacturing Company.

New Laboratory for Engineers

A NATIONAL laboratory for research into manufacturing problems is to be established by the institution of Production Engineers in England.

This decision is considered to be of the greatest importance in maintaining technical progress in all branches of British industry.

MEETINGS

WESTERN METAL CONGRESS AND EXPOSITION—*Pan-American Auditorium and Biltmore Hotel, Los Angeles, Calif. March 21-25. Sponsored by the American Society for Metals with 18 national technical societies cooperating. Wm. H. Eisenman, secretary, Pan-Pacific Auditorium, Los Angeles, Calif.*

SOCIETY OF AUTOMOTIVE ENGINEERS—*National Passenger Car Meeting, Hotel Statler, Detroit, Mich., March 28–30. John A. P. Warner, secretary, 29 W. 39th St., New York, N. Y.*

AMERICAN SOCIETY OF AUTOMOTIVE ENGINEERS — *National Tractor Meeting. Schroeder Hotel, Milwaukee, Wis. April 14–15. John A. P. Warner, secretary, 29 W. 39th St., New York, N. Y.*

AMERICAN GEAR MANUFACTURERS ASSOCIATION—*22nd Annual Meeting, General Brock Hotel, Niagara Falls, Canada, April 18–20. J. C. McQuiston, secretary, Penn-Lincoln Hotel, Wilkinsburg, Pa.*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—*National Meeting, Sagimore Hotel, Rochester, N. Y. May 10–12. C. E. Davies, secretary, 29 W. 39 St., New York.*

AMERICAN FOUNDRYMEN'S ASSOCIATION—*42nd Annual Convention, Cleveland Public Auditorium, Cleveland, Ohio, May 16–19. The Foundry Show will open Saturday, May 14 and continue to Thursday, May 19. D. Avey, secretary, 222 W. Adams St., Chicago, Ill.*

A sum of £10,000 is to be subscribed by industries towards the cost of the laboratory and the Government will, it is understood, make a grant.

One of the problems to be studied will be the most effective and economic use of machine tools which are the basis of the mass-production system. This point is of particular consequence when essential parts for aeroplanes or guns have to be turned out with extreme accuracy at mass-production rates.

According to present plans the laboratory is to be established at Loughborough College, and will be under the direction of Dr. Schlesinger, who is considered one of the world's greatest experts in technical research on machine-tool design and operation. He is at present at Brussels University.

Bolt Sizes Schedule Now Available

PRINTED copies of Simplified Practice Recommendation R169-37, machine, carriage, and lag bolts (steel)—stock production sizes, are now available and can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.

The recommendation, which was proposed and developed by the industry, establishes a simplified schedule of stock production sizes for steel square-head machine bolts, steel hexagon-head machine bolts, steel square-neck carriage bolts, and steel lag bolts.

This schedule of recommended stock production sizes for bolts became effective on November 1, 1937, and is subject to regular review by a standing committee of the industry.

Do You Know That—

AN ELECTRIC conduit made of wood pulp has been perfected. The new conduit will neither rust or corrode. (75)

ABSORBENT and tough when wet, two qualities heretofore never found in any one paper, are combined in a new type of paper. This paper can be slushed around in water, washed with soap and even boiled for hours without disintegrating. Wetting does not appreciably decrease its strength. (76)

Case Histories in Patent Law

H. A. TOULMIN, JR.

[Editor's Note: *We wish to emphasize that in consenting to furnish this column wherein general explanations of the law in specific patent cases are set forth. Col. H. A. Toulmin, Jr. wants it clearly understood "that each actual case should be submitted to your own patent attorney who is the only one familiar enough to advise you accurately." The purpose of these explanations is to give a better general understanding of questions of patent law.*]

CASE HISTORIES—NO. 5

QUESTION: Who owns an invention —the employee who made it or his employer?

ANSWER: This is a matter that should be definitely covered in the contract of employment, for while the law is clean-cut and well determined, in some cases it is based upon considerations of public policy rather than on individual justice.

For instance, if an employee makes an invention on his employer's time, using his employer's materials and tools, he is bound to allow the employer to use the invention in his shop—but nowhere else. If the employer moves away or sells the shop he cannot retain the right to use the invention.

If the employee is hired to make inventions—as is frequently the case among members of a research, design, or development department staff—every invention he makes pertaining to the employer's line of business belongs to the company as defined by his contract. But if such an employee invents something out of the company's line, not covered by the contract, the employer cannot hold the invention.

It is wise to cover the question of inventions in every employment contract, for only in that way can the rights of all parties be properly safeguarded.

TYPICAL CASES: From his work in the shop an employee got what proved to be a very brilliant idea, which he developed at home on his own time with his own materials. Because the invention was in the employer's line of work the employer felt that he had a valid claim to the invention. The courts held, however, that the employee had a right to his ideas provided he used his own time and materials to develop them.

Another employer hired an inventor for the specific job of inventing a process and machine for making a certain type of spring. The employee succeeded and then claimed that the invention was his and that his employer, who had been paying him a salary for that specific purpose, had only a license to use the improvements. The Supreme Court of the United States decided the invention belonged absolutely to the employer. Such cases of an employee trying to secure double compensation through both salary payments and royalties are quite common.

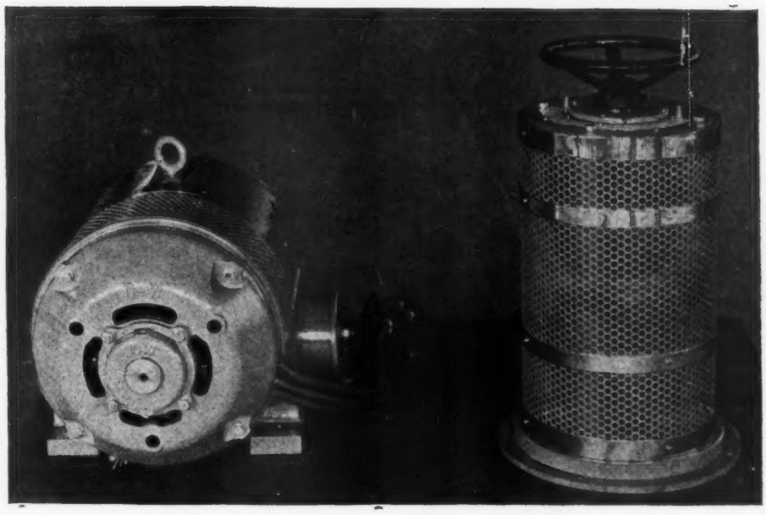
One manufacturer had agreed in an employment contract to pay an employee a salary plus a royalty on any inventions he made. But, when the employee made a worth-while invention the employer refused to pay royalties, the refusal being based, perhaps, on the decision in the foregoing case. The court held that, even though the employee used the employer's materials and facilities and was being paid a salary for inventing, the contract was proper and binding and that the inventor should receive royalties.

With respect to inventions, the status of an executive of a company is quite different from that of an ordinary employee. In a recent case an executive, who had been employed to help make the business successful, partly through improving the products, made an invention on his own time. The court held that while an ordinary employee would have certain rights in an invention so made, the executive held a position of trust and that he must make over his invention to the company.

To assure that the right person will own the patent it is necessary to be careful that his name appears on the patent papers as inventor. Only the man who actually makes the invention can legally sign the papers. If any one else does, and it is discovered after the application is filed or the patent issued, the patent is invalid.

To have the wrong man sign the papers is very common in concerns which maintain design, research or development departments. Sometimes, regardless of who actually made the invention, the papers are signed by the head of the department or by the principal inventor under whom the real inventor was working. While it is common practice in many companies to have important papers signed by department heads rather than by underlings, it is bad business where patents are concerned because the true inventor must make the oath.

New Materials and Parts



A.C. "Polyspeed" Motors

A 3-phase a.c. motor with a speed regulator unit which provides motor speed characteristics in general resembling those of a d.c. motor with variable-voltage control. The motor has a laminated stator core with a winding similar to that of a 3-phase induction motor, the stator winding being connected directly to a 3-phase power line.

Laminated rotor core carries a single winding similar to a normal d.c. armature winding and is connected to a commutator in the usual manner. Three brush studs per pair of poles with brushes in fixed position are provided. Instead of short circuiting the motor brushes, a 3-phase voltage opposite to the voltage generated in the motor by the revolving magnetic field of the stator is applied. The magnitude of this counter voltage is adjustable by means of a speed regulator which consists of two single phase induction type voltage regulators placed in one frame, the two rotors being mounted on a common shaft.

The primary windings on the rotor are connected through flexible leads to the same 3-phase source of power as the stator windings of the motor. The secondary windings are on the stationary element of the speed regulator and are connected to form a source of 3-phase voltage which is applied to the motor brushes to provide adjustable voltage for the regulation of the motor speed. Secondary voltage of the regulator depends upon the position of the regulator primary coils with respect to the secondary coils. When the axis of a primary coil coincides with the axis of a secondary coil, voltage induced in the secondary coil is a maximum. With axes at right angles secondary voltage is zero. By adjusting the secondary voltage, the motor can be made to run at any speed from standstill to slightly below synchronous which latter is when the secondary voltage is reduced to zero and the brushes are short circuited. By reversing the 3-phase voltage applied to the rotor brushes the motor will run through synchronous speeds and on up to still higher speeds.

These motors are suitable for operating at any speed from 1,800 down to 600 r.p.m., the lower speed limit being determined by the limited effectiveness of the cooling fan, mounted on the motor shaft, when operating at speeds below 600 r.p.m. By using a separate motor-driven blower for air cooling, the "polyspeed" motor can be operated continuously at any speed down to practically standstill.

Some outstanding advantages of these new motors are fully continuous speed regulation without rheostat losses; shunt motor characteristics with speed practically independent of load; constant torque throughout the entire speed range; simplicity of construction; and across-the-line starting. Crocker-Wheeler Electric Mfg. Co., Ampere, N. J.

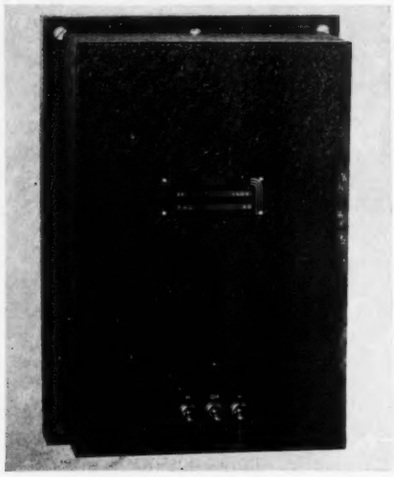
Mill Duty Safety Switch

New window-type mill duty safety switch developed for quick and safe inspection of the blades from the outside. The window is 3/16 in. shatter-proof glass held securely in place from the inside. A sponge rubber gasket is used to cushion the glass and seal the opening in the cover. The new switch is basically the same as their standard Type A mill duty line with quick make and quick break mechanism; pressure-type fuse clamps; non-current carrying hinge posts; double-break air-blanketer contacts; silver plated blades and jaws; unit

pole construction and interlocked cover with key release and provisions for padlocking. Available in standard sizes from 30 to 1,200 amp. up to 600 volts, fusible and non-fusible. Cutler-Hammer, Inc., 296 N. 12th St., Milwaukee, Wis.

Vibrating Voltage Regulator

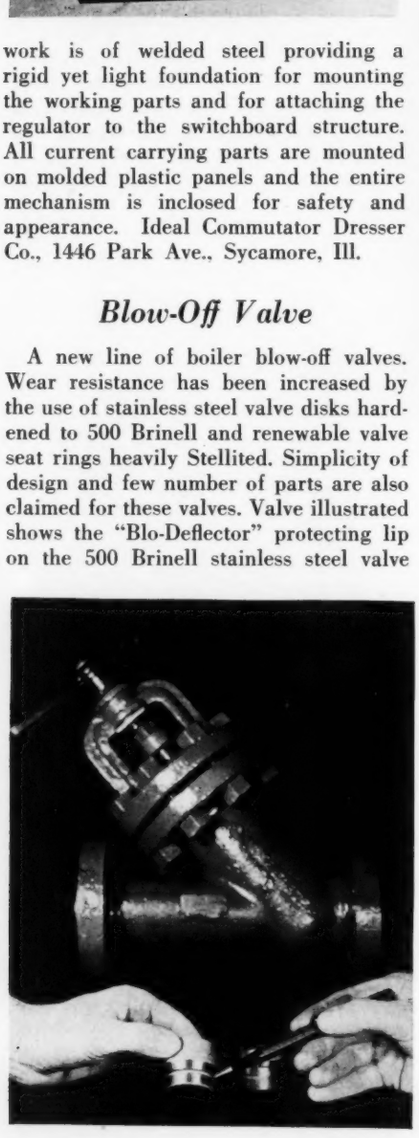
Designed primarily for the voltage control of a.c. generators which are subject to wide load variations. The regulator maintains the correct a.c. voltage on the generator by alternately opening and closing a set of rheostat shunting relay contacts across the exciter field rheostat. The rheostat shunting relay contacts are controlled by the main control element and the time that the contacts are closed as compared to the time they are open determines the exciter armature voltage which in turn maintains the correct a.c. generator voltage. The regulator frame-



work is of welded steel providing a rigid yet light foundation for mounting the working parts and for attaching the regulator to the switchboard structure. All current carrying parts are mounted on molded plastic panels and the entire mechanism is inclosed for safety and appearance. Ideal Commutator Dresser Co., 1446 Park Ave., Sycamore, Ill.

Blow-Off Valve

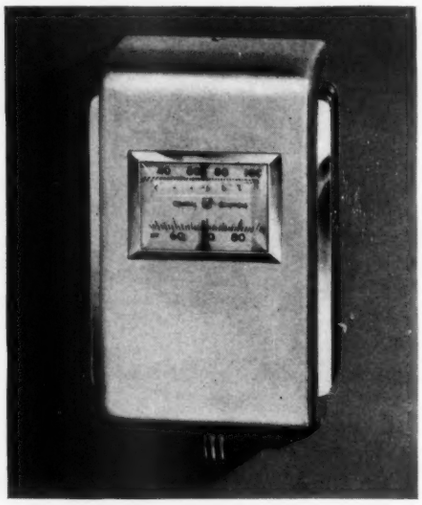
A new line of boiler blow-off valves. Wear resistance has been increased by the use of stainless steel valve disks hardened to 500 Brinell and renewable valve seat rings heavily Stellited. Simplicity of design and few number of parts are also claimed for these valves. Valve illustrated shows the "Blo-Deflector" protecting lip on the 500 Brinell stainless steel valve



disk, which is for the purpose of protection against wear. Available in both straightway and angular type valves for boiler and economizer pressures up to 1,660 lb. in compliance with A.S.M.E. code requirements. Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport, Conn.

Line Voltage Thermostat

A new line voltage room thermostat similar in appearance to the standard General Controls low voltage "Metrotherm." Finished in a soft satin-silver and chrome. An accurate bimetal thermometer is incorporated, giving quick response, greater visibility and elimination of breakage or separation of liquid. Electrical rating 5 amp. 110 volts, 2½ amp. at 220 volts. Locking device is standard. General Controls Co., 450 E. Ohio St., Chicago, Ill.



Non-Hardening Putty

A new plastic compound, known as "Plasticalk," developed to take the place of putty and other substances used for cementing glass to glass, metal or wood and for calking crevices, making joints of various kinds and other purposes. It does not dry, harden, crack, shrink or lose its bond with age, retaining its plasticity and adhesiveness indefinitely. It is unaffected by water or humidity and does not support fungus-growth. Applied with an ordinary putty knife and when in place will not sag or flow, even if heated by a near-by electric lamp. Maas & Waldstein Co., 438 Riverside Ave., Newark, N. J.

Corrosion-Resistant Plastic

A sprayable, corrosion-resistant plastic called "Amercoat." Claimed to be resistant to dilute solutions, up to 20 per cent concentration of sulphuric, hydrochloric, nitric, acetic, hydrofluoric and other acids. Also resistant to caustics and hydrogen sulphide gas within a temperature range of from —50 deg. to 150 deg. F. This plastic material can be sprayed with an ordinary spray gun on concrete, steel or wood and is claimed not to peel or readily chip off after hardening, even when subjected to vibration or limited bending. Is normally applied to a thickness of 1/64 in. but any desired thickness up to 1/16 in. may be sprayed on. Naturally colorless, it may be pigmentized to practically any color desired. Amercoat has tensile strength in excess of 200 lb. per sq. in. and a smooth semi-glazed surface. Abrasion resistant properties are comparable to rubber, phenolic resins and similar materials. The Amercoat protective covering is made up of three separate solutions, a prime coat, an enamel and a seal coat. Each solution is quick drying to an extent so that application procedure may be considered continuous. Where necessary to slow up rate of drying a suitable retarder is supplied. American Concrete & Steel Pipe Co., Box 1428, Arcade Station, Los Angeles, Calif.

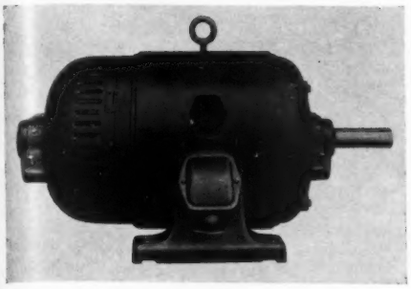
Brass Valves

A new line of brass screwed end globe and check valves for 350 lb. per sq. in. steam pressure at 550 deg. F. temperature. Can be used on non-shock oil or gas lines up to 1,000 lb. per sq. in. pressure. The globe pattern brass valve is of the union bonnet type except the

2-in. type, which has a bolted bonnet. Plug type disk is nickel alloy and body seat ring is Exelloy. Stuffing box packing can be renewed when valve is wide open and under pressure. Horizontal lift check valve also has union bonnet except the 2-in. size which has a bolted cap. Disks are of the piston-guided type. seats are renewable and screw in the rings of special nickel alloy. The horizontal swing check valve can be used for horizontal or upward flow, has screwed cap and tapped hole in the body to facilitate regrinding the disk. All these valves are available in sizes from ½ to 2 in. Crane Co., 836 S. Michigan Ave., Chicago, Ill.

Polyphase Motor

A low-starting current, high-starting torque motor having a locked torque of about twice full load torque and a locked current of from three to three and a half times full load current. Rotor



is the primary member, the winding of which is connected to the line when the motor is operating. The stator is the secondary and has two windings, one a high-resistance short-circuited winding and the other a low-resistance insulated winding. The former, at the bottom of the stator slots, is protected by a thermal device that disconnects the motor upon overheating. Motor has no centrifugal switch, a time delay relay in the control circuit short circuiting the low-resistance winding after a definite lapse of time. Available in sizes up to 40 hp. Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo.

Photoelectric Controller

A photoelectric control unit designed expressly for machinery applications and known as "Photoswitch." Both the control and light source are in a weatherproof housing suitable for installation in any factory location. Model A10 is a general purpose unit, providing control in less than 1/30 of a second. It operates on 115 volts a.c. or d.c. List price is $40 with light source. Model A20, same price as Model A10, is for long distance signal systems up to 60 ft. from the light source to controller, both in daylight and darkness. Counter Model C30 combines in one compact housing a complete photoelectric control and a durable electric counter. Tube circuit is connected directly to counter without interposed relay, thus assuring positive and fast count. List price $50 complete with light source. Photoswitch Incorporated, 21 Chestnut St., Cambridge, Mass.

Copper Tubing Fittings

A line of brass fittings for flared copper tubing, the fittings including 90 deg. and 45 deg. elbows, tees, couplings, reducers, adapters and flanging tools, in sizes from 3/8 to 1¼ in. Cast parts of the fittings are made of brass, compression nuts are forged brass and flanging tool is made of steel. The fittings are rated at 175 lb. per sq. in. water working pressure. Crane Co., 836 S. Michigan Ave., Chicago, Ill.

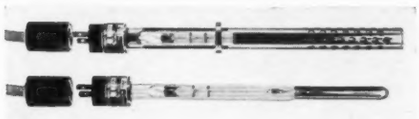
Double-Reduction Speed Reducers

A new series having higher ratios combined with greater capacities than formerly available in their double-reduction worm units. Worm gears are of gear bronze and worms of hardened steel, all shafts being mounted on Timken bearings and oil seals are used on all shaft openings in housing. Available

in capacities ranging up to 2 hp. with speed ratios as high as 4,000 to 1, in both horizontal and vertical types. Chas. Bond Co. Arch St., Philadelphia, Pa.

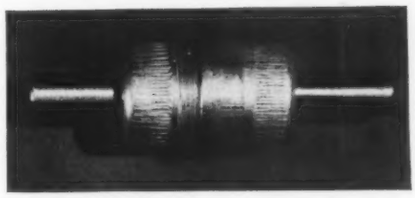
Thermo-Regulator

A new regulator and relay claimed to be accurate to within 1/10 of 1 deg. F. and known as the Red-Top thermo-regulator. Available as unarmored or armored as illustrated, for controlling temperatures within a range from —30 deg. to +500 deg. F. It can be set to any holding temperature and reset as desired, simply by tipping and transferring mercury between the bulb and the reservoir. The new Red-Top thermostats are non-adjustable, similar in appearance to the thermo-regulators illustrated, the difference being that only one specified temperature control point specified when ordering, is possible. H-B Instrument Co., 2518 N. Broad St., Philadelphia, Pa.



New Flexible Coupling

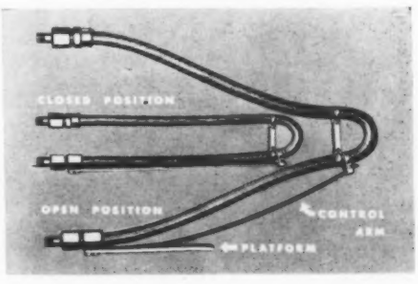
Known as "Torflex," this coupling transmits the torque through rubber bushings which firmly grip the driven and driving shafts by the pressure de-



veloped when tightening the cases. These are threaded right or left-hand, selected so that driving torque tends to increase the pressure of the bushings on the shafts. Features include a cushioned drive that is torsionally flexible, serves an electric insulator, gives overload protection, requires no machining of the shaft for keys or setscrews and is noiseless in operation. Available in sizes from 3/8 to 1½ in. shaft diameter for maximum torques ranging from 40 in. lb. to 650 in. lb. Gordon Engineering Co., 3576 Gratiot Ave. Detroit, Mich.

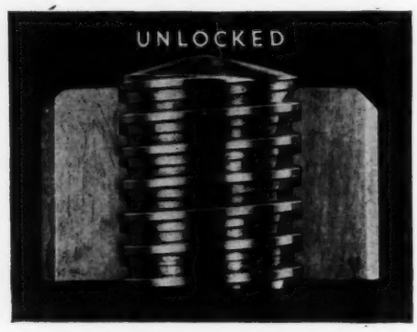
Flexible Hose Mounting

For automatically regulating the flexing of flexible hose, it consists primarily of a small compact platform and control arm which are rigidly fastened to the hose coupling for the purpose of supporting the slack and assuring effective drainage of the hose. It is claimed that hose flexing is equalized, excessive strain on the hose is eliminated, and wear at the couplings is greatly reduced. Available in three styles to take care of long or short travel and wide, medium or zero opening while in "closed" position. Furnished as a complete connector unit known as "Packless Flex-Control Self-Draining Hose." Packless Metal Products Corp., 37-24 29th St., Long Island City, N. Y.



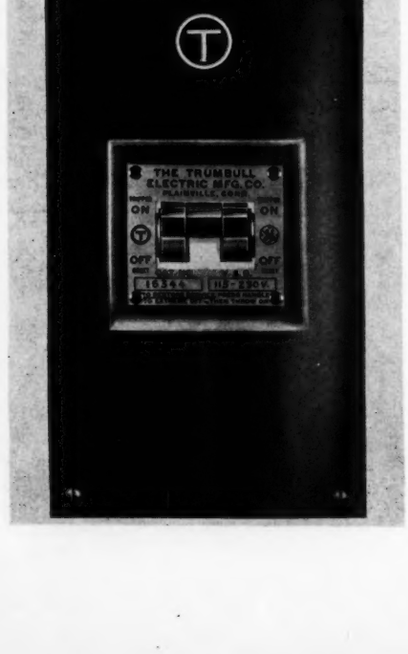
Self-Locking Screws

An improvement over the original Dardelet screw thread profile known as the Dardelet Relieved Profile, the details of which can be seen in the illustration which shows the nut in the unlocked position. By relieving the root of the bolt thread it is claimed that the nut is free spinning up to the point where a locking action begins. The bolt tension is then developed rapidly and the grip of the locking is improved. The lower step being undercut 0.003 to 0.005 in. gives the thread profile equivalent to the free fit of Class 2 American National threads, while in the locked position the fit will be more intimate than the Class 4 fit. Dardelet Threadlock Corp., 55 Liberty St., New York, N. Y.



Circuit Breaker

A non-industrial circuit breaker to provide separate circuit metering in a compact device, or for service entrance range or hot water heater circuits. Known as Type M multi-breakers, available for 2 and 3 wire, solid neutral service with either grounded or insulated neutrals. Breaker capacities include 15, 20, 25, 35 and 50 amp. Measures 9x4⅞ in., for flush or surface mounting. The Trumbull Electric Mfg. Co., Plainville, Conn.



Manufacturers' Publications

A. C. Polyspeed Motors — Crocker-Wheeler Electric Mfg. Co., Ampere, N. J. Bulletin 251, 8 pages, 8½x11 in. Describing in detail the construction and operation of an entirely new design of adjustable speed a.c. motors with speed regulators.

Belt Lacing Products—The Bristol Co., Waterbury, Conn. Bulletin 728. Covering Bristol Steel belt lacing products with application information on the various styles and sizes available, together with price list.

Caster and Wheel Manual—Darnell Corp., Ltd., Long Beach, Calif. Catalog 38, 5½x8½ in. 192 pages. Complete specification data, dimensional drawings, price list, etc., on the Darnell line of casters available for a wide variety of uses.

Flow Meters—The Foxboro Co., Foxboro, Mass. Folder, 8½x11 in. Describing their Type 7000 universal flow meter built to withstand pressures up to 1,500 lb. Also describes Type 7417 for use where a meter is desired with a uniform flow scale able to record temperature and pressure on the same chart with the flow.

Industrial Glass—United States Glass Co., South 9th and Bingham Sts., Pittsburgh, Pa. Folder, 8½x11 in. Describing their facilities for the engineering and manufacture of glass for industrial and commercial purposes.

Neoprene—E. I. duPont de Nemours & Co., Wilmington, Del. "The Neoprene Notebook," Vol. I, No. 1, 4 pages, 8½x11 in. The first number of a new publication which is planned to give engineering information, laboratory data and application reports on neoprene.

Pencils—Eagle Pencil Co., Inc., 703 E. 13th St., New York, N. Y. Folder, 8½x11 in. Describing turquoise drawing pencils, being a reprint of the official report issued by the Investigating Committees of Architects and Engineers. Tables of the range of degrees of hardness of the black lead pencils and a listing of the 30 colored pencils are included.

Recording Thermometers—The Foxboro Co., Foxboro, Mass. Bulletin 198-1, 40 pages, 8½x11 in. Descriptions of the various thermometers of this company, giving the range of characteristics, thermal systems and special bulbs available for recording thermometers and pyrometers.

Separator Magnets—The Electric Controller & Mfg. Co., 2700 East 79th St., Cleveland, Ohio. Bulletin 910, 8x10½ in. 8 pages. Presenting the outstanding advantages and applications of their line of separator magnets for removal of tramp iron. Includes a table of approximate recommendations for the various sizes of magnets and a table of weights and dimensions.

Self-Locking Nuts—Elastic Stop Nut Corp., 1003 Newark Ave., Elizabeth, N. J. Loose-leaf booklet, "Elastic Stop," 48 pages, 8½x11 in. A comprehensive explanation of the construction of the elastic stop nut, a standard nut with the height increased to incorporate a fiber collar. Explanatory sketches and cartoons help to explain the construction and outstanding features. Numerous typical applications are illustrated with line drawings giving general application details. Tables of dimensions of the standard and special nuts are included. Special nuts include cap nuts, thumb nuts, bearing spanner nuts, knurled nuts, etc.

Speed Reducers—Chas. Bond Co., 617-623 Arch St., Philadelphia, Pa. Catalog CA-60, 28 pages, 3½x6 in. Illustrating and describing the various types of Bond speed reducers, including the recently introduced Type B double reduction units.

Strainers—Sheffler-Gross Co., Inc., Drexel Bldg., Philadelphia, Pa. Bulletin 100, "Duoflo Strainers," 4 pages, 8½x11 in. Briefly describing the Duoflo suction strainers and the Duoflo discharge strainers, including tables of ratings and dimensions.

Stainless Steel—Rustless Iron and Steel Corp., 3400 E. Chase St., Baltimore, Md. "Handbook of Rustless Stainless Steels," 60 pages, 8½x11 in. Describing the types of rustless stainless steels, their properties, heat-treatment and workability.

Switches—Automatic Switch Co., 154 Grand St., New York, N. Y. Bulletin 920A, 8½x11 in. 8 pages. A comprehensive bulletin on remote control switches, well illustrated with comprehensive drawings and photographs showing details of operations, advantages, etc

Switches—General Electric Co., Schenectady, N. Y. Leaflet, GEA-1565B. Descriptive data, advantages and ratings of CR7009 a.c. magnetic reversing switches.

Temperature Controls—H-B Instrument Co., Inc., 2518 N. Broad St., Philadelphia, Pa. "Blue Book—Part 4," 8 pages, 8½x11 in. Describing the new features of H-B thermo-regulators, relays and solenoid valves.

Vanadium in Cast Iron—Vanadium Corporation of America, 420 Lexington Ave., New York, N. Y. Bulletin 8½x11 in. 28 pages. Describes the improved physical properties of cast irons employing varying amounts of vanadium. Numerous charts and tables list the specifications of various vanadium-containing irons, and a number of commercial applications of vanadium irons are illustrated.

Wire Cloth—The Cambridge Wire Cloth Co., Cambridge, Md. Bulletin, 8 pages, 8½x11 in. Describing Monel metal woven wire conveyor belts with illustrations of typical applications and descriptions of the various belt constructions available.

BALL BEARINGS—New Departure Div., General Motors Corp., Bristol, Conn. Booklet R-6, "Interchangeable Ball Bearings for Replacement," 20 pages, 8½x11 in. Containing numerically arranged lists of competitive ball bearings, together with the corresponding numbers of interchangeable New Departure bearings. Space is also devoted to alphabetically arranged definitions of letters and letter combinations used by various manufacturers to identify bearing characteristics.

BEARINGS—Tyson Roller Bearings Corp., Canton, Ohio. Folder, 8½x11 in. Data on several types of Tyson tapered roller bearings.

COPPER STEEL—United States Steel Corporation Subsidiaries, Box 176, 434 Fifth Ave., Pittsburgh, Pa. Booklet, "A Little Copper in Steel Gives a Lot of Protection," 16 pages, 3½x6¼ in. Presenting the results of the latest American Society for Testing Materials experiments on the atmospheric corrosion resistance of various grades of steel and iron, a chart indicating the superiority of copper steel as compared to non-copper bearing steel and iron, applications of copper steel in various industries, and a list of fabricated products for which copper steel is particularly adapted.

CONVEYOR CHAINS—Link-Belt Co., 2410 West 18th St., Chicago, Ill. Book 1637, 12 pages, 8½x11 in. Descriptive data and illustrations covering the new Link-Belt conveyor chains for handling bottles, cans, glassware, etc. Dimensional drawings, tables of specifications and price lists are included.

COLORED PORCELAIN ENAMELS.— Ferro Enamel Corp., Cleveland, Ohio. Booklet, 8 pages, 5½x8 in. A discussion concerning reproduction of colored porcelain enamel is presented in the booklet, "The Color Question—Blended Basic or Basic Blends."

COMPRESSORS—Ingersoll Rand Co., 11 Broadway, New York, N. Y. Bulletin 2118, 8½x11 in., covering their Type 30 line of small industrial compressors and vacuum pumps, ranging in size from ¼ to 15 hp.

DIESEL ENGINES—Caterpillar Tractor Co., Peoria, Ill. Booklet, Form 4253, 32 pages, 8¼x10¾ in. An attractively presented booklet giving a brief resumé of the outstanding features of the diesel engines manufactured by Caterpillar. Mechanical features of the engines and materials used are discussed.

DREDGE BUCKETS—American Manganese Steel Div., American Brake Shoe & Foundry Co., 956 Ferry St., Oakland, Calif. Folder, 8½x11 in. Data on their Amsco rivetless lip dredge buckets.

ELECTRIC DRIVE SELECTOR—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Bulletin, 12 pages, 8½x11 in. Requirements which must be met in selecting a motor are described and illustrated in this booklet, "Electric Drive Selector and Hints on Maintenance."

FLEXIBLE METAL HOSE—Packless Metal Products Corp., 37-24 29th St., Long Island City, N. Y. Bulletin 100, 24 pages, 8¾x11¼ in. A new "Engineering Data File" containing descriptive data and illustrations, specifications and data sheets covering Packless seamless flexible metal hose and couplings.

GENERATORS—Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill. Folder, 8½x11 in. Price lists on Janette alternating and direct current special generators.

GRINDING WHEEL GUIDE—American Emery Wheel Works, Providence, R. I. Catalog 10, 45 pages, 5x7 in. Presenting a brief concise description of American grinding wheels, what they contain, how they are made, and their application to modern grinding practices.

"INDUSTRIAL FRICTION MATERIAL"—Johns-Manville, 22 East 40th St., New York, N. Y. Booklet, Form FM-7A, 8 pages, 8½x11 in., containing comprehensive data and illustrations on the complete lines of industrial brake linings and blocks and clutch facings manufactured by the company for all types of industrial equipment.

LIGHT TRANSMITTERS—Electronic Control Div., United Cinephone Corp., Long Island City, N. Y. Loose-leaf sheet, 8½x11 in. Containing information on their light sources, light transmitter units, carrier frequency transmitter units, scanning units, photocell receiving units and accessories.

MAGNETIC SEPARATOR—S. G. Frantz Co., 161 Grand St., New York, N. Y. Booklet, 16 pages, 8½x11 in. A well-presented and illustrated booklet on the new Frantz Ferro Filter, a new type magnetic separator for use in the process industries.

MEASURING INSTRUMENTS—Carl Zeiss, Inc., 485 Fifth Ave., New York, N. Y. Catalog Fe200e, 128 pages, 6¼x8½ in. General catalog on their precision measuring instruments. Divided into five sections covering instruments for measuring and gaging lengths; measuring and checking angles and angular divisions; checking gears; measuring threads; and miscellaneous measuring, gaging and inspection instruments.

MOTOR-GENERATORS — Electric Specialty Co., 209 South St., Stamford, Conn. Bulletin 242L, 8 pages, 8x10½ in. Data and specifications covering their line of motor generator sets, converters and dynamotors, many of which have been redesigned.

NICKEL ALLOYS—The International Nickel Co., Inc., 67 Wall St., New York, N. Y. Three new publications: "Nickel Alloys for High and Low-Temperature Refinery Service," "High Strength Corrosion-Resisting Rivets for Marine Construction," and "Nickel Alloy Steels in Oil Well Tools."

PEARLITIC MALLEABLE IRONS—Belle City Malleable Iron Co., Racine, Wis. Folder, 8½x11 in. Following a brief discussion on pearlitic malleable irons, the special qualities and physical properties of Belmalloy, the pearlitic malleable produced by this company, are covered.

PLASTIC COATING—American Concrete & Steel Pipe Co., Box 1428, Arcade Station, Los Angeles, Calif. Booklet, 8 pages, 8¼x11 in. Covering the characteristics and physical properties of Amercoat, a corrosion-proof, sprayable, plastic coating for concrete, steel and wood.

POWER TRANSMISSION EQUIPMENT—Boston Gear Works, Inc., 2, North Quincy, Mass. Catalog 52, 320 pages, 3½x6 in. The 1938 edition of their general catalog containing complete descriptions and price lists of all Boston power transmission equipment, together with engineering data and information.

RELAYS—General Electric Co., Schenectady, N. Y. Loose-leaf Sheet, GEA-2711, 8x10½ in. Descriptive data on their Type HEA multi-contact auxiliary relays for six or ten circuits.

ROLLER BUSHINGS—Orange Roller Bearing Co., Inc., 557 Main St., Orange, N. J. Catalog, 8 pages, 8½x11 in. Following a description of the Orange roller bushings, the booklet is devoted to tables listing the standard sizes with dimensions and carrying capacities. A number of typical installations are illustrated.

ROLLER CHAINS—Diamond Chain & Mfg. Co., 443 Kentucky Ave., Indianapolis, Ind. Catalog 617, 96 pages. Data on the use of roller chains for motor drives, machinery and conveyor applications, much of which has never before been made available. Sections are devoted to engineering data, dimension and capacity tables, chain attachments for conveying and timing mechanisms, noncorrosive chains, and sprockets.

SCREWS, BOLTS, NUTS—Pheoll Mfg. Co., 5700 Roosevelt Road, Chicago, Ill. 1938 Catalog, 108 pages. An illustrated listing of standard screws, bolts, nuts and allied products manufactured by the company.

SILICON BRONZES—Bridgeport Brass Co., Bridgeport, Conn. Handbook, 80 pages, 5½x8¾ in. A technical handbook, "The Duronze Manual," covering the physical properties and applications of four high-strength silicon bronzes sold by this company under the trade name Duronze alloys. A section is devoted to engineering data giving tables on corrosion resistance, machinability data, welding practices, weight tables, etc.

VALVES—Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport, Conn. Bulletin 8500, 4 pages, 8½x11 in. Descriptive data on the Hancock blow-off valves with "Blo-Deflector" seat and disk.

VIBRATION—The Korfund Co., Inc., 48-15 Thirty-Second Place, Long Island City, N. Y. Bulletin, 8 pages, 9x11½ in., entitled "Smoother Sailing With Korfund," covering the Korfund resilient mountings "Vibro-Dampers" and their applications.

WELDING—The Lincoln Electric Co., Dept. D-457, Cleveland, Ohio. 32 pages, 11x8½ in. A well-presented and illustrated booklet prepared as an aid in applying electric welding to the design of machines and machinery structures, setting forth the experiences of many manufacturers who have redesigned their products for arc welded construction. Numerous illustrations of products formerly built by some other method and their modern arc welded counterparts are shown.

WIRE PRODUCTS—Globe Wire Div., Firth-Sterling Steel Co., McKeesport, Pa. Booklet, 8 pages, 8½x11 in. Containing illustrations and descriptions of wire products ranging from watch spring wire to tool steel drill rods. Also includes a table of drill rod sizes, weights per ft., and list prices per lb.

Books and Bulletins

Manual of Porcelain Enameling

EDITED BY J. E. HANSEN, *Service Director, Ferro Enamel Corp. and published for that company by The Enamelist Publishing Co., 4150 56th St., Cleveland, Ohio. 520 pages, 6x9 in. Clothboard covers.*

A textbook dealing with the application of wet process enamels for sheet iron and cast iron, being a revision of "The Technique of Vitreous Enameling," published in 1932.

The various chapters include a brief history of the art, design of sheet iron parts for enameling, cast iron for enameling purposes, and then chapters that go into the details of the successive steps in the process of applying vitreous fired enamels. Four chapters are devoted to descriptions of shop equipment, one chapter to plant management and the closing chapter is a dissertation on the future of the art. A convenient appendix, "The Enameler's Dictionary," defines terms peculiar to the porcelain enameling industry.

Procedure Handbook of Arc Welding

FIFTH EDITION. *976 pages, 6x9 in. Semi-flexible covers. Published by The Lincoln Electric Co., Cleveland, Ohio. Price $1.50 in U.S.A., $2 elsewhere.*

A large portion of this handbook is devoted to methods of designing for arc welded construction. Many design examples of machinery elements and units are included. Because design is so closely allied with the welding methods, the first five chapters of the book are devoted to welding methods and equipment, the technique of welding, procedures, speeds and costs for welding mild steel, structure and properties of weld metal, and a chapter on the weldability of various metals. Detailed instructions for the use of welding symbols, showing the types of symbols in use, are included. A considerable amount of technical data on the strength and ductility of welds are also included.

By means of graphs are shown the welding speed and weight of electrode required for various types of welds and plates of various thicknesses. Numerous tables are included to assist the designer in estimating his welding cost and to aid the production man in the welding procedure.

Part 6, which is devoted to designing for construction of machinery, takes about 160 pages. In addition to formulas and equations for calculating stresses, numerous typical designs of standard machine elements and constructions are shown. The book contains more than 1,200 illustrations.

Fundamentals of Machine Design

C. A. NORMAN, E. S. AULT, I. F. ZAROBSKY. *486 pages, 6x9 in. Green clothboard covers. Published by The Macmillan Co., 60 Fifth Ave., New York, N. Y. Price $4.25.*

Professor Norman of Ohio State, Professor Ault of Purdue and Professor Zarobsky of the University of Toledo state in the preface of this book, "It has been the aim of the authors to show by means of typical problems the basic principles underlying machine design and the necessity, in many instances, of modifying a strictly theoretical design. . . ." Written primarily for a college textbook, typical problems are given at the end of each chapter. In twenty chapters the authors treat the design of the various machine elements such as gears, brakes, clutches, springs, cams and other elements.

In presenting the design procedure of various machine elements the equations are derived in sufficient detail so that it requires only a knowledge of elementary strength of materials to follow derivations. The authors have included numerous typical designs and constructions, more than 400 illustrations being scattered throughout the book. The last chapter of the book is devoted to vibratory stresses and the methods for solving problems encountered in vibrations.

Segmental Functions

C. K. SMOLEY. *First Edition, 475 pages, 4x7 in. Flexible covers. Published by C. K. Smoley and Sons, Scranton, Pa. Price $5.*

The principal feature of this book is that it offers simple methods for solving problems relating to circular segments. By means of tables the area of any circular segment is obtained when any two of the five elements of the segment, namely, the arc, the chord, the radius, the central angle or the height, are known. Similarly, tables are given for finding the lengths of arcs. Forty pages of text preceding the tables explain their use.

Tables are also given for laying out circular curves. Part 2, covering 185 pages, contains five-place tables of logarithms of numbers from 0 to 10,000, logarithms of feet, inches and fractions of an inch from 0 to 200 ft., advancing by thirty-seconds from 0 to 20 ft., by sixteenths from 20 to 100 ft., and then by eighths. Circumferences, areas, cubes, square roots and similar tables commonly used in engineering calculations are also given.

Proceedings of the A.S.T.M.

PART *I. 1,365 pages, 6x9 in. Clothboard covers. Published by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.*

The complete proceedings of the 40th annual meeting of the American Society for Testing Materials held in New York City, June 28 to July 2, 1937. Committee reports, A.S.T.M. tentative standards and tentative revisions of standards are included.

PART *II. 707 pages, 6x9 in. Clothboard covers. Published by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa.*

Containing all of the papers and discussions of the papers presented at the 40th annual meeting of the American Society for Testing Materials, held in New York City, June 28 to July 2.

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Industrial Electric Heating

PARTS 2 AND 3. *6x8¼ in. Part 2, 62 pages, Part 3, 116 pages. Paper covers. Published by Arbeitsgemeinschaft zur Forderung der Elektrowirtschaft (AFE), Berlin W35, Buchenstrasse 5, Germany. Price each, RM1.*

These booklets set forth in German text the rapid development of the different types of electric furnaces. Part 2 covers the fundamental principles of electric heating technology. Part 3 is devoted to typical applications of electric heating covering induction furnaces, radiant heat furnaces and resistance furnaces of various designs. A comprehensive tabulation shows the type of furnace and electric heating for different applications. More than 1,000 different electric furnace applications are illustrated.

Elektrowarmetagung Berlin—5. Juni 1936

100 pages, 8¼x11 in. Paper covers. Published by Wirtschaftsgruppe Elektrizitatsversorgung, Einemstrasse 1, Berlin W62, Germany. The Arbeitsgemeinschaft zur Forderung der Elektrowirtschaft (AFE), Berlin W35, Buchenstrasse 5, Germany.

This booklet in German text contains the papers presented at the meeting of the German Electrical Industries at Berlin on June 5, 1936. Subject matter covered by the papers includes the general fields of application of electric heating, new technical developments, radiant electric furnaces, induction furnaces and resistance furnaces.

Standard Tolerances for Forgings

For Forgings Under 100 Pounds Each

Adopted by the Drop Forging Association, February 11, 1937

TOLERANCES shall be either "Special" or "Regular". "Special" Tolerances are those which are particularly noted in the specifications and may state any or all tolerances in any way as occasion may require. Special Tolerances apply only to the particular dimension or thing noted. In all cases where Special Tolerances are not specified, Regular Tolerances shall apply.

"Regular" Tolerances are divided into two divisions—"Commercial Standard" and "Close Standard." "Commercial Standard" tolerances are for general forging practice, but when or where extra close work is desired involving additional expense and care in the production of forgings, "Close Standard" may be specified. "Close Standard" may be specified for one or more of the following classes. When no standard is specified, "Commercial Standard" shall apply.

Classes

Regular tolerances are applicable to the following classes:

1—Thickness
2—Width: (a) shrinkage and die wear; (b) mismatching; (c) trimmed size
3—Draft Angle
4—Quantity
5—Fillets and Corners.

TABLE I—THICKNESS TOLERANCES

(Inches)

Net weights up to — lb.	*Commercial* −	*Commercial* +	*Close* −	*Close* +
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.114	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Class 1—Thickness Tolerances

Thickness tolerances shall apply to the overall thickness of a forging. When applied to drop hammer forgings, they shall apply to the thickness in a direction perpendicular to the main or fundamental parting plane of the die. When applied to upset forgings, they shall apply to the thickness in a direction parallel to the direction of travel of the ram, but only to such dimensions as are inclosed by and actually formed by the die.

Class 2—Width and Length Tolerances

Width and length tolerances shall be alike and shall apply to the width and/or length of a forging. When applied to drop hammer forgings, they shall apply to the width or length in a direction parallel to the main or fundamental parting plane of the die, but only to such dimensions as are enclosed by and actually formed by the die. When applied to upset forgings, they shall apply to the width or length in a direction perpendicular to the direction of travel of the ram.

Width and length tolerances shall consist of three subdivisions:

Class 2. (a) Shrinkage and die wear tolerance.
Class 2. (b) Mismatching tolerance.
Class 2. (c) Trimmed size tolerance.

Class 2 (a)—Shrinkage and Die Wear

Shrinkage and die wear tolerances shall apply to that part of the forging formed by a single die block only. They shall not apply to any dimension crossing the parting plane. They shall be the sum of the shrinkage tolerances and the die wear tolerances as given in Table II. The shrinkage tolerances and die wear tolerances shall not be applied separately, but shall only be used as the sum of the two. They shall not be so applied as to include draft or variation thereof.

TABLE II—SHRINKAGE AND DIE WEAR

(Inches)

Shrinkage	Plus		Die Wear		
Lengths or Widths up to — in.	*Commercial* + or −	*Close* + or −	*Net wt. up to — lb.*	*Commercial* + or −	*Close* + or −
1	0.003	0.002	1	0.032	0.016
2	0.006	0.003	3	0.035	0.018
3	0.009	0.005	5	0.038	0.019
4	0.012	0.006	7	0.041	0.021
5	0.015	0.008	9	0.044	0.022
6	0.018	0.009	11	0.047	0.024
Each additional inch add	*0.003*	*0.0015*	*Each additional 2 lb. add*	*0.003*	*0.0015*
For example			*For example*		
12	0.036	0.018	21	0.062	0.031
18	0.054	0.027	31	0.077	0.039
24	0.072	0.036	41	0.092	0.046
36	0.108	0.054	51	0.107	0.054
48	0.144	0.072	71	0.137	0.069
60	0.180	0.090	91	0.167	0.084

Class 2 (b)—Mismatching Tolerance

Mismatching is the displacement of a point in that part of a forging formed by one die block of a pair, from its desired position when located from the part of the forging formed in the other die block of the pair. Mismatching does not include any displacement caused by variation in thickness of the forging, but is only the displacement in a plane parallel to the main or fundamental parting plane of the dies.

Mismatching tolerances are independent of, and in addition to, any other tolerances.

TABLE III—MISMATCHING TOLERANCE

Net weight up to — lb.	*Inches Tolerance*	
	Commercial	*Close*
1	0.015	0.010
7	0.018	0.012
13	0.021	0.014
19	0.024	0.016
Each additional 6 lb. add	*0.003*	*0.002*
For example —		
37	0.033	0.022
55	0.042	0.028
79	0.054	0.036
97	0.063	0.042

Class 2 (c) Trimmed Size Tolerances

The trimmed size shall not be greater nor less than the limiting sizes at the parting plane imposed by the sum of the draft angle tolerances and the shrinkage and die wear tolerances.

Class 3—Draft Angle Tolerances

Draft angle tolerances are the permissible variations from the standard or nominal angle of draft.

TABLE IV—DRAFT ANGLE TOLERANCES FOR DROP HAMMER FORGINGS

(Degrees)

	Nominal angle	*Commercial limits*	*Close limits*
Outside	7	0–10	0–8
Inside holes and depressions	10	0–13	....
	7	....	0–8

FOR UPSET FORGINGS

	Nominal angle	*Commercial limits*	*Close limits*
Outside	3	0– 5	0–4
Inside holes and depressions	5	0– 8	0–7

Class 4—Quantity Tolerances

Quantity tolerances shall be the permissible over—or under—run allowed for each release or part shipment of an order. Any shipping quantity within the limits of over—and under—run shall be considered as completing the order. Commercial and close tolerances shall be the same amounts.

TABLE V—QUANTITY TOLERANCES

Number of pieces on order		*Over-run*	*Under-run*
		Pieces	*Pieces*
1–	2	1	0
3–	5	2	1
6–	19	3	1
20–	29	4	2
30–	39	5	2
40–	49	6	3
50–	59	7	3
60–	69	8	4
70–	79	9	4
80–	99	10	5
		Per cent	*Per cent*
100–	199	10	5.0
200–	299	9	4.5
300–	599	8	4.0
600–	1,249	7	3.5
1,250–	2,999	6	3.0
3,000–	9,999	5	2.5
10,000–	39,999	4	2.0
40,000–	299,999	3	1.5
300,000 up		2	1.0

Class 5—Fillet and Corner Tolerances

Fillet and corner tolerances apply to all meeting surfaces even though drawings and/or models indicate sharp corners, unless such drawings and/or models have or indicate (even though actual dimensions are not specified) fillet and/or corner dimensions of larger radii than the following standards, in which case such actual or indicated larger dimensions shall be considered as actually specified and the tolerances shall be "Special Tolerances."

Fillet tolerances apply to inside corners and edges in all cases in which surfaces meet at an angle less than 180 degrees.

Corner tolerances apply to outside corners and edges in all cases in which surfaces meet at an angle greater than 180 degrees.

When a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase towards the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

The radii of fillets and corners may be any value not greater than those given in Table VI.

TABLE VI—FILLET AND CORNER TOLERANCES

(Radii in Inches)

Net weights up to lb.	*Commercial*	*Close*
0.3	3/32	3/64
1	1/8	1/16
3	5/32	5/64
10	3/16	3/32
30	7/32	7/64
100	1/4	1/8